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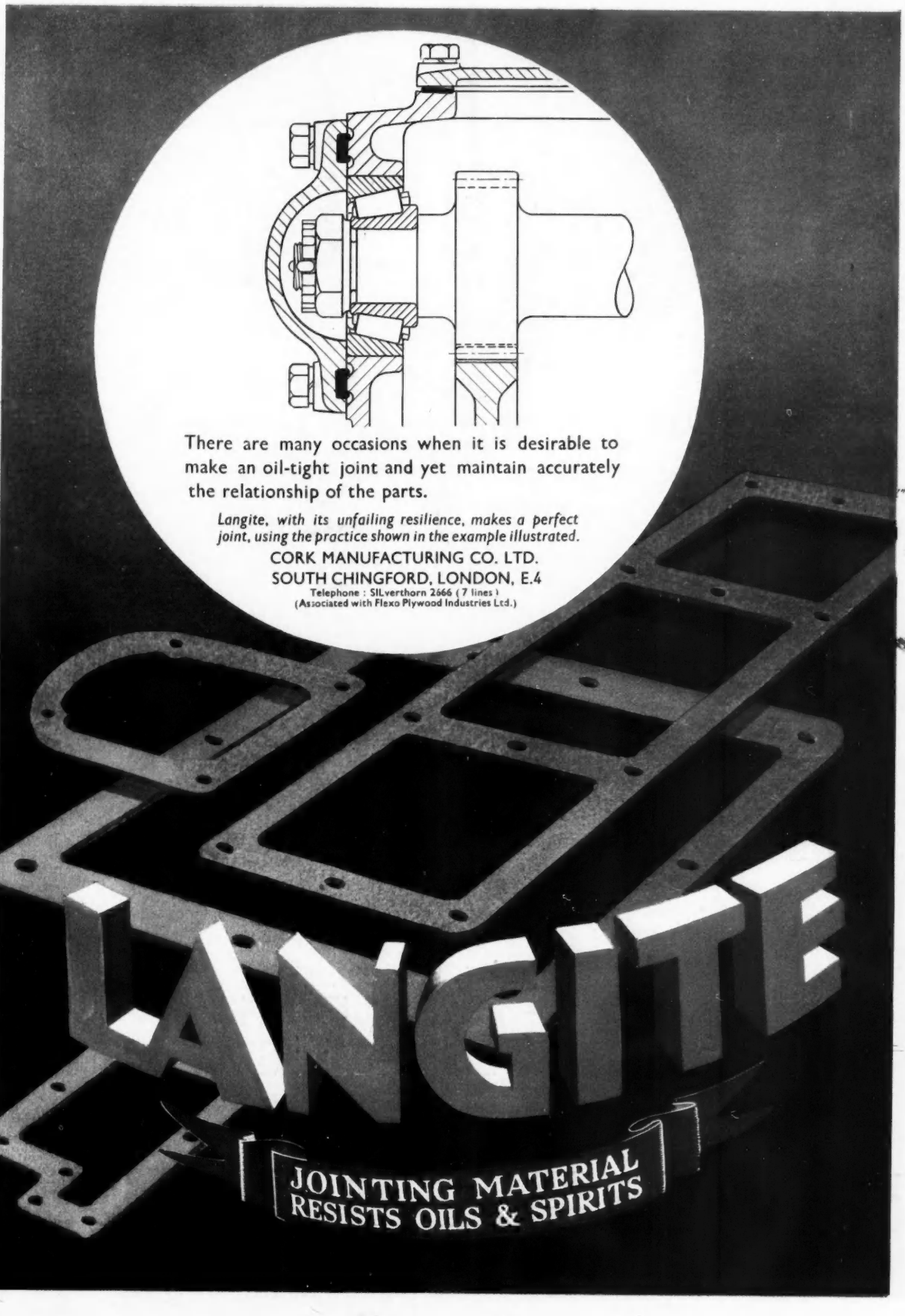
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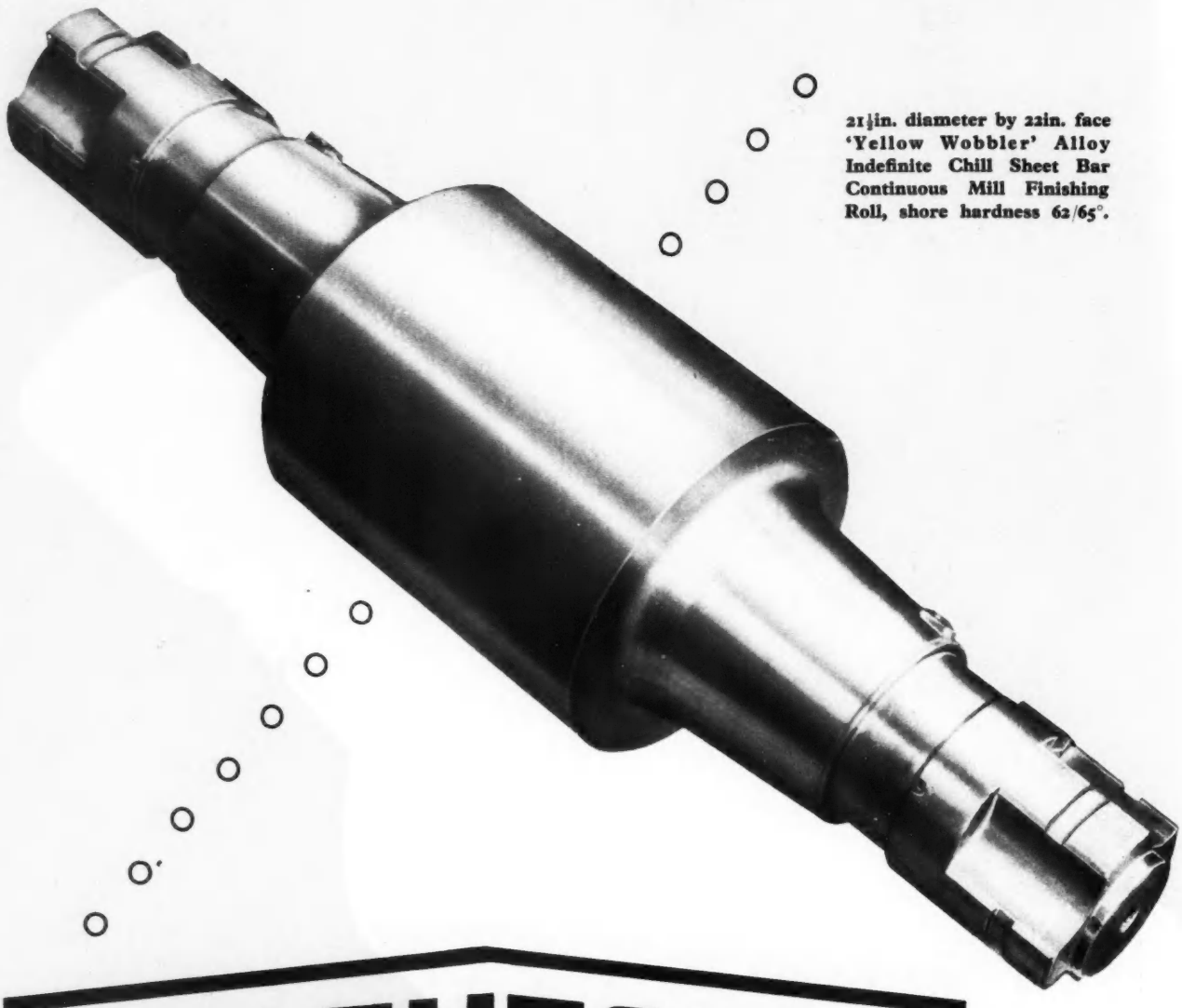

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THE ENGINEER

ESTABLISHED 1856

Vol. 196 No. 5103

NOVEMBER 13, 1953

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NOTICE TO READERS
All letters intended for insertion in 'The Engineer' or containing questions should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications. No undertaking can be given to return drawings or manuscripts; correspondents are therefore requested to keep copies.

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Advertisements received by Mid-day Tuesday will appear in the issue of Friday the same week. Orders must be accompanied by a remittance.

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PUBLIC APPOINTMENTS

LOUGHBOROUGH COLLEGE OF TECHNOLOGY

LEICESTERSHIRE

Principal: H. L. HASLEGRAVE, Wh. Sc., Ph.D., M.A., M.Sc.

HEAD OF WORKSHOP TRAINING AND PRACTICE

Applications are invited for the above post, duties to commence as soon as possible.

Candidates should have had considerable practical experience of a responsible character, should hold a University Degree or be a Corporate Member of a professional Engineering Institution and, preferably, should have had teaching experience.

The College provides four and five years' full-time Engineering Diploma Courses in which alternate weeks are spent in the College workshops, where practical training is given under a production system. The person appointed will be responsible for the organisation and carrying out of practical training, design and production in the College workshops, and the teaching of workshop technology subjects.

Salary will be paid according to the scale £1340–£25–£1490; the post is superannuable.

Application forms and further particulars may be obtained from the Registrar, to whom completed forms should be returned as soon as possible. E5990

COLLEGE OF TECHNOLOGY, BIRMINGHAM

DEPARTMENT OF MECHANICAL ENGINEERING

SENIOR LECTURER

Applications are invited for the post of SENIOR LECTURER for Theory of Machines and Strength of Materials in the Design Section of the department. Candidates should have an Honours Degree or equivalent. Teaching experience is essential and research experience will be an advantage.

The person appointed will be required to take up duty on January 1st, 1954, or as soon afterwards as possible.

The salary will be in accordance with the Burnham (Further Education) Scale for Senior Lecturers (Men: £1040 by £25 to £1190).

Further particulars and form of application may be obtained from the Registrar, College of Technology, Suffolk Street, Birmingham, 1, on receipt of stamped, addressed foolscap envelope. Completed forms should be returned to him not later than two weeks after the appearance of this advertisement.

C. McCAW,
Clerk to the Governing Body.

E6050

COUNTY OF LEICESTER

COLLEGE OF FURTHER EDUCATION, LOUGHBOROUGH

Principal: Dr. D. J. LYSAGHT, M.Sc.

HEAD OF DEPARTMENT, GRADE II

Applications are invited for the post of HEAD of the ENGINEERING DEPARTMENT. High qualifications in mechanical engineering are required. Considerable experience in teaching, together with industrial experience are desirable. Previous applicants are eligible to re-apply by letter. Salary in accordance with that of Head of Department, Grade II, of the Burnham Scale.

Further details and forms of application may be obtained from the Principal, to whom they should be returned within fourteen days of the appearance of this advertisement. E6017

THE WAITEMATA ELECTRIC POWER BOARD

NEW ZEALAND

ASSISTANT ELECTRICAL ENGINEER

Applications are invited for the above appointment; candidates should hold a Degree in Engineering from an approved university, or should be Corporate or Graduate Members of the Institution of Electrical Engineers, and have had considerable experience in the design, installation and operation of distribution and transmission systems up to 33,000 volts, including overhead, underground and substation equipments.

The salary will be at a commencing rate of £1000 per annum. Candidates should be between the ages of 30 and 40 years.

Further particulars and application forms may be obtained from the undersigned.

PREECE, CARDEW AND RIDER.
8, 10 and 12, Queen Anne's Gate,
London, S.W.1. E6035

THE REINFORCED CONCRETE ASSOCIATION

ASSISTANT SECRETARY

The Reinforced Concrete Association invites applications for the appointment of ASSISTANT SECRETARY. Candidates must be Chartered Civil or Structural Engineers with a broad knowledge of reinforced concrete design and construction and its constituent materials. Salary not less than £900 p.a. —Applications, which will be confidential to the Secretary until after a preliminary interview, to be addressed to him at 94/98, Petty France, London, S.W.1, in an envelope marked "Assistant Secretary." E2775

CITY COUNCIL OF SINGAPORE

CITY ELECTRICAL ENGINEER'S DEPARTMENT

PASIR PANJANG POWER STATION

ASSISTANT RESIDENT MECHANICAL ENGINEER

Applications are invited for the post of ASSISTANT RESIDENT MECHANICAL ENGINEER for the Pasir Panjang Power Station, which is at present in operation with two 25MW turbo-alternators and two 187,500 lb. per hour boilers, 625 lb. per sq. in. pressure and 825 deg. F. superheat, and for which extensions are now in hand covering three 25MW turbo-alternators, five 187,500 lb. per hour boilers, and one 2MW gas turbine house set.

Applicants should be Corporate or Graduate Members of one of the Senior Engineering Institutions or possess equivalent qualifications, and have had a sound training in mechanical and electrical engineering with practical experience in steam power plant and ancillary equipment.

The appointment is for a two years' agreement, commencing in April, 1954, at a salary of 1450 dollars per month inclusive of transport allowance (1.00 dollar equals 2s. 4d.).

Free first-class return passages by normal route for the officer, his wife and children up to three full passages in all, provided no child exceeding the age of twelve years, will receive a passage.

Half salary from the date of leaving the United Kingdom to the arrival in Singapore and on the return voyage.

Vacation leave of 28 days after completion of two years' resident service to commence from the date of arrival in the United Kingdom, provided the return voyage does not exceed 26 days.

Rent of City Council quarters, if available, 50 dollars per month.

Applications, endorsed "Assistant Resident Mechanical Engineer," stating age, qualifications and experience, should be forwarded to the undersigned within 14 days of the date of this advertisement.

PREECE, CARDEW & RIDER,
Consulting Engineers.
8, 10 and 12, Queen Anne's Gate,
Westminster, London, S.W.1. E6036

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

HYDRAULICS RESEARCH STATION

EXPERIMENTAL OFFICERS & ASSISTANT EXPERIMENTAL OFFICERS

Department of Scientific and Industrial Research require EXPERIMENTAL OFFICERS and ASSISTANT EXPERIMENTAL OFFICERS (unestablished initially) at the Hydraulics Research Station, Wallingford, for research as follows:—(1) Civil Engineer for experimental work on hydraulic models of rivers, estuaries, harbours, &c.; reference number E/497/53/A. (2) Soil Mechanics Engineer for work on classification and analysis of river and coast sands and silts; reference number E/498/53/A. (3) Civil or Mechanical Engineer experienced in control of workshops, buying of plant and equipment and design work; reference number E/499/53/A. (4) Assistant Librarian (technical library experience an advantage); reference number A/268/53/A. Candidates for E.O. posts should be at least 26 and have a pass Degree in Engineering or equivalent; post-graduate experience desirable. Inclusive annual remuneration for 45½-hour week, £669-£823 (men), £572-£696 (women). For A.E.O. posts candidates should be at least 18 and have H.N.C. in Engineering subjects or G.C.E. at advanced level in Scientific or Mathematical subjects or equivalent qualification. Inclusive annual remuneration for a 45½-hour week: £272-£593 (men), £272-£499 (women), according to age. Prospect of permanent established posts for E.O.s under 31 and A.E.O.s under 28.—Application forms, quoting appropriate reference number, from M.L.N.S., Technical and Scientific Register (K), 26, King Street, S.W.1. Closing date 5th December, 1953. E5979

BRITISH PRODUCTIVITY COUNCIL

NATIONAL INDUSTRIAL FUEL EFFICIENCY SERVICE

GENERAL MANAGER

The National Industrial Fuel Efficiency Service invites applications for the post of GENERAL MANAGER to the Service.

The appointment is one of great responsibility and the salary envisaged is within the range of £3000 to £4000 or higher for a man with exceptional qualifications and particularly suitable experience.

The primary objects of the company are to provide general advice to industrial and non-industrial (other than domestic) establishments, and to give practical help to secure the most efficient and economical use of all forms of fuel, heat and power. The general manager will be located in London and will be directly responsible to the board of directors for the management of the company's affairs and for the employment of the available technical resources in the direction most calculated to achieve the objects of the Service.

The selected candidate will be a man of high administrative ability and must have had considerable practical experience of the utilisation of fuel and power. A recognised technical qualification in the field of combustion and thermal engineering is desirable, but personality and drive are the first essentials.

Applications, which will be treated as strictly confidential, giving date of birth and full details of education, training, qualifications and experience, should be sent, not later than 24th November, 1953, to the company at Thames House South, 6th Floor, Millbank, London, S.W.1. E2790

SURREY COUNTY COUNCIL

COUNTY ARCHITECT'S DEPARTMENT

ASSISTANT MECHANICAL ENGINEER, GRADE VI

Applications are invited for the appointment of ASSISTANT MECHANICAL ENGINEER, Grade VI, commencing salary £670 p.a., rising by annual increments of £20/£25 to a maximum of £735 p.a., plus London allowance of up to £30 p.a., according to age.

Applicants should be Corporate Members of the Institution of Mechanical Engineers and/or Institution of Heating and Ventilating Engineers, and should be experienced in preparation of specifications, drawings and estimates for the installation and maintenance of heating, ventilating and hot water supply services in large buildings.

The appointment will be subject to the provisions of the Local Government Act, 1937, and the successful applicant will be required to pass a medical examination.

Applications, stating age, qualifications and experience, and accompanied by copies of three recent testimonials, should be sent to the County Architect, Surrey County Council, County Hall, Kingston-upon-Thames, not later than the 21st November, 1953.

Canvassing, either directly or indirectly, will disqualify a candidate for consideration.

W. W. RUFF,
Clerk of the Council.
County Hall,
Kingston-upon-Thames. E6010

KENT RIVER BOARD

ENGINEER'S DEPARTMENT

ENGINEERING ASSISTANTS

Applications are invited for the following appointments in the Engineer's Department:—

(i) ENGINEERING ASSISTANTS, Grade VI, £670 to £735.

(ii) JUNIOR ENGINEERING ASSISTANTS, Grade A.P.T. I–V, £465 to £645.

Applications for the Grade A.P.T. VI appointments should be Chartered Civil Engineers and have had experience in the design and construction of civil engineering works, preferably in connection with land drainage and sea defences.

Applications for the Grade A.P.T. I–V appointments will be graded according to experience and should hold an Engineering Degree or have passed Parts A and B of the Associate Membership Examination of the Institution of Civil Engineers. Opportunities exist for applicants in this grade to serve as assistants under agreement to the engineer.

National Conditions of Service apply to the appointments, which are within the establishment of the Board, and, subject to medical examination, the successful candidates will be specified as contributory employees under the Local Government Superannuation Act, 1937.

Applications with the names and addresses of three referees, should be forwarded to the Engineer to the Board, 78, College Road, Maidstone.

A. G. STIRK,
Clerk of the Board.
River Board House,
London Road,
Maidstone. E6009

METROPOLITAN WATER BOARD

APPOINTMENT OF WELL ENGINEER

There is a vacancy for a WELL ENGINEER on the permanent staff. Salary scale £778 to £1025 per annum by annual increments, commencing salary according to age, qualifications and experience. Maximum age 45 years. It is a condition of the appointment to and the holding of the position that the selected candidate shall be and continue to be a subscribing Corporate Member of the Institution of Civil Engineers.

Candidates should possess a sound knowledge of hydro-geology and have had responsible experience in well and borehole sinking and in the supply of water from wells.

A house may be available, if required, in a good neighbourhood, at an inclusive rental of £129 per annum.

Particulars of the appointment and a form of application may be obtained from the undersigned on receipt of a stamped, addressed foolscap envelope, quoting reference G.7, and completed applications must arrive not later than 14th December, 1953.

W. S. CHEVALIER,
Clerk of the Board.
Offices of the Board, New River Head, Rosebery Avenue, London, E.C.1. E6004

THE PARSONS AND MARINE ENGINEERING TURBINE RESEARCH AND DEVELOPMENT ASSOCIATION

RESEARCH ENGINEER

The Parsons and Marine Engineering Turbine Research and Development Association requires a RESEARCH ENGINEER for experimental development work on gas turbines. Applicants should have an Honours Degree in Engineering and experience on running machinery. Gas turbine experience is not essential, but an aerodynamic background would be an advantage. A good salary will be paid, depending on age, qualifications and experience.—Candidates should apply in writing to the Research Director Pametrada Research Station, Wallsend. E5996

FIFE COUNTY COUNCIL

COUNTY ENGINEER'S DEPARTMENT, CUPAR

ENGINEERING ASSISTANTS

Applications are invited for appointments as ENGINEERING ASSISTANTS on salary Grade A.P.T. V.—£600, rising to £650 per annum. Applicants should be qualified engineers, preferably experienced in the design and construction of works for water supply and/or drainage. Consideration will be given to meeting the housing needs of the appointed applicants and placing on the scale may be given according to qualifications and experience. The County Council have on hand a large programme of new construction of varied and interesting new works, including aqueducts, service reservoirs and booster stations for water supply, also purification works and pumping schemes for the disposal of sewage. Further information regarding the vacancies and application forms may be obtained on request from the County Engineer, Belfield, Cupar. All applications should be lodged with the undersigned not later than 21st November, 1953.

MATTHEW POLLOCK,
County Clerk.
County Buildings,
Cupar, Fife,
4th November, 1953. E6021

LONDON ELECTRICITY BOARD

CHIEF ENGINEER'S DEPARTMENT

Applications are invited for the following positions in Central London.

STRUCTURAL ASSISTANTS and STRUCTURAL DRAUGHTSMEN (Construction Branch).

Applicants for positions of Structural Assistant should have experience in the design and detailing of reinforced concrete heavy foundations, frames, superstructures, and other structural works. Applicants for Structural Draughtsmen should have experience in detailing reinforced concrete structures.

The posts are graded under Schedule "D" of the National Joint Board agreement as Grade 5—£595 7s. to £704 11s. and Grade 6—£458 to £595 7s. per annum, respectively, inclusive of London Allowance. Commencing salaries will be dependent upon qualifications and experience.

ARCHITECTURAL DRAUGHTSMAN

Applicants should be neat draughtsmen and preferably have had several years' experience in an architect's office.

The post is graded under Schedule "D" of the National Joint Board agreement as Grade 6—£458 to £595 7s. per annum, inclusive of London Allowance.

Application forms obtainable from Establishment Officer, 46, New Broad Street, E.C.2, to be returned completed by 21st November, 1953. Please enclose addressed foolscap envelope and quote Ref. V/16[illegible] EE on all correspondence. E5872

SURVEYOR OF SHIPS (SHIP)

HONG KONG GOVERNMENT

SURVEYOR of SHIPS (SHIP) required by the Hong Kong Government Marine Department for appointment on probation for pensionable employment. Normal tour is four years. Salary, according to experience, in scale equivalent to £140 rising to £1981 a year. Additional allowance up to £295 a year for married men, according to dependents. Free passages. Liberal leave on full salary. Candidates must hold University Degree in Naval Architecture or an equivalent qualification and have attained a position of responsibility in a ship building or ship repair establishment. They must have been trained in the theory and practice of ship design construction and repair and have had subsequent practical experience.

Write to the Crown Agents, 4, Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2A/30149/EH. E5999

BRITISH ELECTRICITY AUTHORITY

NORTH WESTERN DIVISION

ASSISTANT MAINTENANCE ENGINEER (MECHANICAL)

British Electricity Authority, North Western Division, requires ASSISTANT MAINTENANCE ENGINEER (Mechanical) at Stuart Street Generating Station, Manchester, 11. Commencing salary £717. Wide experience of maintenance of modern boiler plant and associated equipment essential. Technical qualifications an advantage.—Applications, quoting Vacancy No. 205/53, to Establishment Officer, British Electricity House, 825, Wilmslow Road, Manchester, 20, before November 21st. E5987

LANCASHIRE COUNTY COUNCIL

COUNTY SURVEYOR'S DEPARTMENT

ASSISTANT ENGINEERS

ASSISTANT ENGINEERS required in the County Surveyor's Department at Preston, in the Bridges Section. Salaries ranging from A.P.T. I (£465-£510) to A.P.T. X (£895-£1025).

Draughtsmen also required in Grades Misc. I (£480-£540) and Misc. VI (£525-£585).

Full particulars and application forms obtainable from County Surveyor, County Hall, Preston. Closing date 23rd November, 1953. E5984

THE ENGINEER

NOVEMBER 13, 1953

National Physical Laboratory Appointment

THE National Physical Laboratory has announced the appointment of Dr. H. Barrell as superintendent of the Metrology Division, in succession to Mr. F. H. Rolt, who retired from that office on November 1st. Dr. Barrell joined the staff of the N.P.L. in 1923, and was associated with the work of Mr. J. E. Sears on determination of the metre and the yard, on wavelengths of light and the refractive index and dispersion of air. More recently he has been in charge of the research work carried out in the Metrology Division into optical and microwave interferometry directed towards improving the precision of length measurements. Although Dr. Barrell's work has been mainly on the physical side, he has had considerable experience of engineering metrology, especially in recent years. During the war, he successfully adapted the pneumatic gauging principle in machines for the simultaneous multiple inspection of several dimensions on certain kinds of ammunition. Dr. Barrell is a Fellow and a member of the board of the Institute of Physics. Mr. F. H. Rolt, who has been superintendent of the Metrology Division since 1946, has been associated for over forty years with the National Physical Laboratory's work in the field of engineering metrology and standardisation. During the second world war, he was seconded to the machine tool control at the Ministry of Supply, serving first as director of gauges and measuring instruments and later as director of jigs, tools and gauges. Mr. Rolt is a member of the Institution of Mechanical Engineers and of the Institution of Production Engineers, and he has made valuable contributions to the work of many committees of the British Standards Institution. In particular, he took a leading part in the post-war British-American-Canadian conferences which resulted in the adoption of the unified screw thread.

British Council's Annual Report

THE annual report of the British Council for the year ended March 31, 1953, has now been published. It surveys the work of the Council in Commonwealth and other overseas countries, and also records that there are now over 18,000 overseas students in this country whose expenditure on fees and maintenance during their training here amount to about £7,000,000 a year. Special emphasis is given in the report to the conclusions reached by the engineering training mission which visited Latin America last year on behalf of the Federation of British Industries. It is stated that, during the year reviewed by the report, 394 British Council scholars and bursars visited this country, of whom 193 were studying scientific subjects, many of them giving particular attention to the application of scientific knowledge. Among them were thirty-six students concerned with civil, mechanical, electrical, chemical and mining engineering. Of the 192 scientific visitors to this country during the year, for whom the Council made arrangements, twenty-eight were concerned with some aspect of engineering science. Altogether, in fact, throughout the year, the Council in this country made individual arrangements for 206 engineers or students of engineering. In addition, special study courses organised by the Council included engineering aspects of public health, and television. Another activity in which the Council was engaged last year was in negotiating for the supply of engineering and technical training equipment—including three aircraft jet engines—to educational institutions in the Middle East and India. Photographs and films on engineering subjects were regularly sent from this country for the use of the Council abroad, and a considerable number of British engineering periodicals were used in the Council's libraries or distributed to universities and other educational establishments.

Inland Waterways

ON Thursday of last week, Sir Reginald Hill, chairman of the Docks and Inland Waterways Board of Management, addressed the Merseyside section of the Institute of Transport on the subject of Britain's inland waterways. He said that, whilst in most cases canal capacities could only be increased substantially at very heavy cost by enlarging locks or the navigation channels themselves, something had been done by ensuring depths to enable existing craft to be loaded to full capacity, by straightening bends, dredging and enlarging bottlenecks. At the recently opened hydraulic research station experiments were proceeding to ascertain whether, by improved design or methods of construction, speeds could be increased without endangering banks by erosion through wash or wave formation and whether pay-load capacity could be increased within the dimensions physically imposed. On the operational side, Sir Reginald continued, there was clearly scope for improving the turn-round times and for reducing idle time of craft and thus obtaining better use of capacity. Greater pay-load capacity had been achieved in three canal craft recently added to the Leeds and Liverpool fleet. They were constructed of high-tensile steel and were capable of carrying 10 per cent more cargo than older craft of similar size. Another innovation which promised speedier and more economical operation where conditions were suitable was the use of light tractors for towing barges. Sir Reginald went on to say that the cost of maintaining the national water tracks with their structures, plant and equipment had averaged £1,400,000 a year over the last three years, and had accounted for two-thirds of the total annual expenditure on the British Transport Commission's waterways. This, he commented, was a heavy burden in relation to some 12,000,000 tons of traffic and gross receipts from all sources of £2,000,000. Dredging and bank protection, the joint heritage of age and and mechanisation, were the chief items of expenditure, and, Sir Reginald added, better and cheaper methods of effecting these were being sought with the aid of research and experiment.

Report of Mines and Quarries Inspectorate

THE Ministry of Fuel and Power has issued this week the report of H.M. Inspectors of Mines and Quarries for the year 1951. The report is required by the provisions of the Metalliferous Mines Regulation Act and the Quarries Act. It states that, in the year reviewed, the number of people employed in quarries averaged 63,200, or about 800 less than in the preceding year. The output of mineral amounted to 147,543,492 tons, which included 11,009,800 tons of opencast coal and 191,400 tons of fireclay produced at opencast coal workings. The report adds that the trend of mechanisation and the results are clearly seen if the output and employment figures are compared with the position twenty-four years ago, when just over 60,000,000 tons of minerals were produced and nearly 82,000 people employed, the yearly average output per person being about 730 tons, against the present 2330 tons. During 1951 the number of inspections made was 7890. The accident rate was somewhat higher than in the preceding year, the figures showing that 62 people were killed and 165 reportably injured. Commenting on quarry accidents, the report says that there was a large increase in 1951 in accidents concerned with machinery, there being eleven people killed and thirty-four injured, as against five killed and nineteen injured in 1950. These increases, the inspectorate says, give rise to concern, particularly as most of the accidents could have been avoided by the exercise of a little more care and foresight by men employed on ordinary operations and day-to-day maintenance. Others, it is stated, would not have happened had proper guards been provided at dangerous parts of machinery or, where provided, had they not been removed while the machinery was in motion.

Sir Philip Haldin

WE record with regret the death of Sir Philip Haldin, which occurred at Lympne Place, Kent, on Saturday last, November 7th. Sir Philip, who was seventy-three, had spent the greater part of his career in the British shipping industry and was a past-president of the Chamber of Shipping of the United Kingdom. Sir Philip was educated at Harrow School, and as a young man was one of the founders of the Court Line. He was also closely associated just prior to the war with the firm of Lamport and Holt, and up to the time of his death was chairman of the ship-owning firm of Haldin and Co., Ltd. Sir Philip occupied many offices concerned with the shipping industry in general. He was a member of the executive councils of the Chamber of Shipping, the Shipping Federation of Great Britain, and of the London General Shipowners Society. His presidency of the first-named body came during the difficult year of 1940–41, when his experience and leadership proved very valuable in the maintenance and operation of this country's merchant fleet. During the war years, Sir Philip was called upon to serve on many committees, including the Ministry of War Transport's shipping advisory council, the advisory committee on merchant shipbuilding, the tramp shipping subsidy and administrative committees, and of the Admiralty's shipping defence advisory committee. Sir Philip was created Knight Bachelor in 1939.

Building Trades Exhibition

ON Wednesday next, November 18th, the twenty-fifth Building Trades Exhibition will be opened at Olympia, in London, and it will remain open until Wednesday, December 2nd. At this exhibition some six hundred firms representative of the fifty trades that comprise the building industry of this country will show their products. In addition to these manufacturers there will also be represented various interested Government departments, research bodies and associations. During recent years there has been a great increase in mechanisation in the building industry with a view to increasing efficiency and reducing labour requirements and costs ; and an exhibition such as this provides an excellent opportunity for builders, constructional engineers and architects to see the latest developments in plant, equipment, materials and methods. Preliminary reports indicate that many manufacturers will be showing new and redesigned products and that there will be much of interest to see upon the stands of the research and development bodies. Particular prominence is to be given in the exhibition to prestressed concrete work and prefabricated structures. The Prestressed Concrete Development Group of the Cement and Concrete Association will be responsible for a section devoted to demonstrations of all known methods of prestressed concrete building technique. In a section devoted to prefabrication several systems will, it is stated, be shown for the first time at this exhibition.

Fig. 15—Zezere Substation from the Air

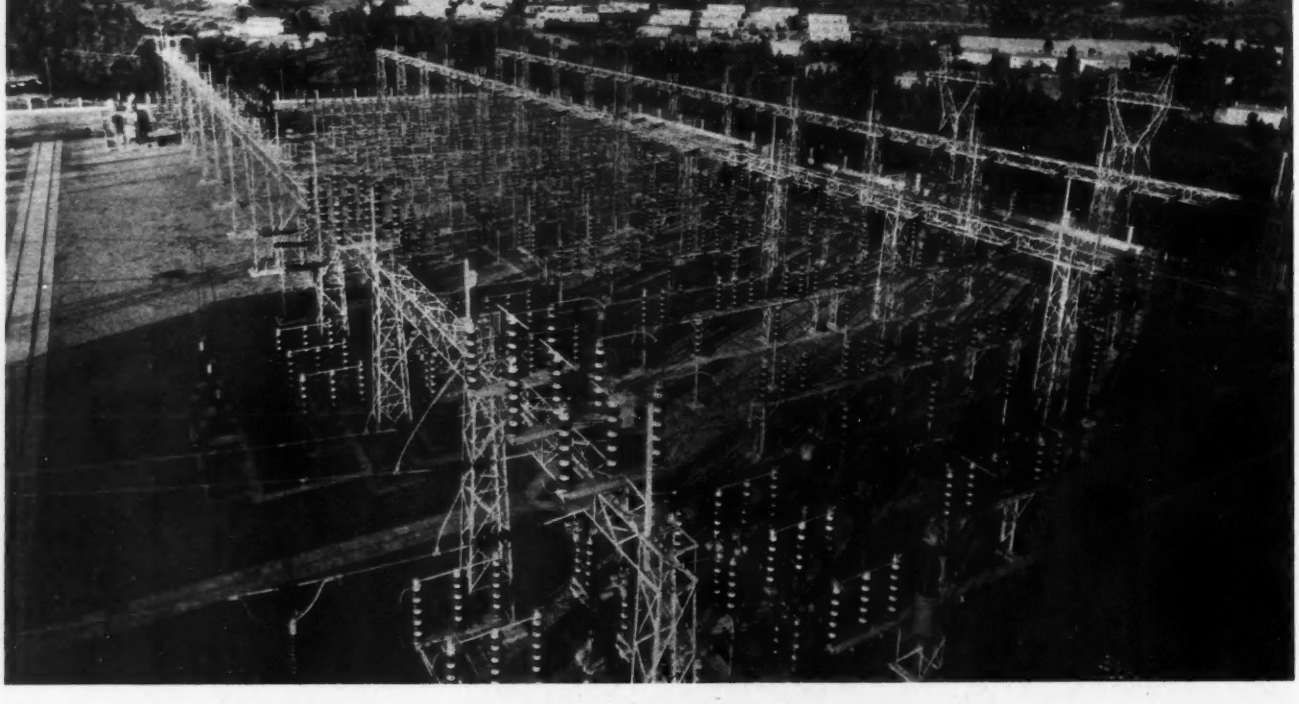


Fig. 16—Outdoor Substation Switchgear at Zezere

Hydro-Electric Development in Portugal

No. III—RIVER ZEZERE SCHEME: CASTELO DO BODE POWER STATION

(*Continued from page 581, November 6th*)

The generating stations at Castelo do Bode on the River Zezere and at Vila Nova on the River Cavado are among the more important hydro-electric developments recently started in Portugal. The Castelo do Bode switchgear is described here.

15kV Switchgear.—Generation is at a nominal 15kV. Each of the three 57·4MVA machines is direct-connected to a 15·5/165kV step-up transformer and switched at 165kV. The 15kV, 2200A connections are of bare copper supported on porcelain insulators housed in chambers in the concrete on the downstream side of the station. In addition, a set of three-phase 2200A busbars is run in a concrete tunnel connecting these chambers. A sheet-steel link cubicle is provided in each generator-transformer circuit, so that the generator can be normally connected to its associated transformer but, in emergency or during maintenance, any generator can be connected to either of the other transformers. The busbars also connect through a 15kV oil circuit breaker, to a loading resistor, capable of dissipating 50MW for testing the generators. Interlocked control switches are provided in the link cubicles to change-over secondary and indicating circuits in line with the position of the links.

Connections to Substation.—Because space is not available in the river valley for the 165kV switchgear, the substation is mounted on top of the right-hand bank. The 165kV overhead connections from the transformers are strung up to the roof of the power station and thence by stub lines, some 800m long, to the substation. The generator breakers are at the substation and are remote-controlled from the power house control room. Surge diverters are connected to each circuit, and are mounted on the power station roof (Fig. 17), as close as practicable to the transformers which they protect.

The substation (Figs. 15 and 16) contains both 165kV and 66kV switchgear, and forms the nodal point for control of power derived from the River Zezere, which, as stated above, will ultimately have three large power stations. At both voltages the switchgear is duplicate-bus on galvanised lattice steel structures, and is of the conventional "low-level" layout, in which the busbars are supported directly from the bus-selection isolators. Busbar and feeder isolators are local-mechanically controlled. Busbar selection is off-load and the isolators are key interlocked with the breakers. Earthing contacts are provided on the outgoing side of circuit isolators.

The 165kV equipment comprises eight bays at present, with provision for an ultimate of fourteen. The present circuits include those for the three generators, feeders to Lisbon and Oporto, an inter-bus transformer to the 66kV switchgear (Fig. 18), and a bus coupler/section equipment. Extensions will cover incoming circuits from the two future power plants of the River Zezere, together with further 165kV feeders and a second inter-bus transformer. The 66kV switchgear comprises only three bays at present (ultimately eight). This gear is to provide interconnection with existing 66kV networks.

Surge protection is not provided on the incoming and outgoing circuits as the switchgear is no more susceptible to surges than the lines themselves. Diverters are mounted at the power station, as mentioned above, for the protection of the generator transformers, and on each side of the inter-bus transformer.

Only the three 165kV generator transformer circuits belong to the Hidro-Electrica do Zezere; the contract for the remainder of the equipment was placed by the Companhia Nacional de Electricidade with the "British Group" and forms part of the country's transmission distribution network.

E.H.V. Circuit Breakers.—All e.h.v. circuit breakers, both 165kV and 66kV, are air-blast equipments. At 165kV four blast heads are used in series (Fig. 19), the heads being mounted in pairs, with a high-speed, rotating, sequence switch between them. The heads are shunted by non-linear resistors for voltage control and the suppression of switching overvoltages. The effectiveness of the four heads to share equally the fault duty is ensured by the symmetrical design, synchronous operation of the contacts, parallel air supplies to the blast heads, and the grading provided by the shunt resistors. The speed of operation from the receipt of a trip impulse to arc extinction is less than 3 cycles. The 66kV breakers are similar, but use only one blast head.

The 165kV feeder breakers are equipped for a single high-speed reclosure with "dead time" adjustable between 10 and 15 cycles. If a fault persists after a reclosure then the breaker retrips and locks out. Facilities are provided for both single and three-phase reclosure with selective control. The breaking capacity at 165kV is 2500MVA and at 66kV, 1000MVA, both ratings being A.S.T.A.

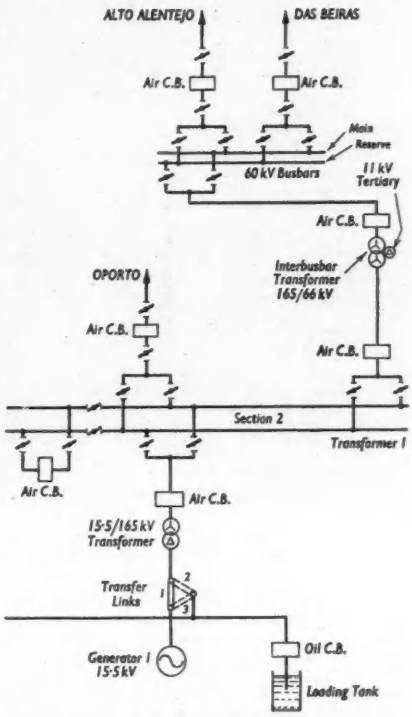


Fig. 18—Zezere Schematic Diagram Omitting Sets Nos. 2 and 3

certified. All breakers are rated for 600A with the exception of the 165kV coupler/section equipment which is for 800A.

Compressor Plant.—The compressor plant, for operation of the breakers, is housed on the substation site and is designed to cater for present and future requirements at both 165kV and 66kV. The compressor sets, valves and pipework are all duplicated to enable any piece of apparatus to be taken down for repair or maintenance, without shutting down the plant. The operation of the compressors is completely automatic, the sets being started and stopped by fall and rise of pressure in the receivers respectively. Initial compression and storage is at 650 lb per square inch, when the air is expanded through reducing valves to half this pressure at the breaker receivers to ensure dryness.

Instrument Transformers.—At both 165kV and 66kV the current transformers are mounted separately from the circuit breakers, the wound type primary being oil-immersed in a steel tank with porcelain primary bushing. Where more than one current transformer is required per phase a common primary is used with multiple cores and secondaries.

Auxiliary Switchgear.—Because of the importance of power station auxiliary supply, it is duplicated and made independent of any source external to the station. Two hydro-electric sets are installed, each of which is capable of supplying the total requirements of the station.

Generation is at 380V, three-phase, three-

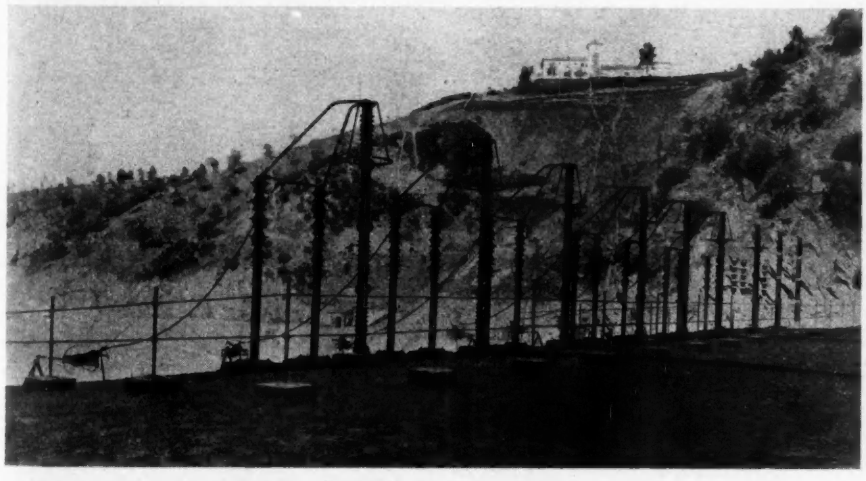


Fig. 17—165kV "Metrosil" Surge Diverters

wire, and power is fed to a single-bus main auxiliaries board with a section breaker between the generator circuits. Normally, this board is run with one generator only in service and the bus section closed. If, for any reason, the running generator trips out, then the standby machine is started automatically and switched in, this sequence being initiated by an undervoltage relay on the bars. The main sets can run for approximately ten minutes without auxiliary supply, while the starting and switching of the standby auxiliary plant is accomplished within three minutes.

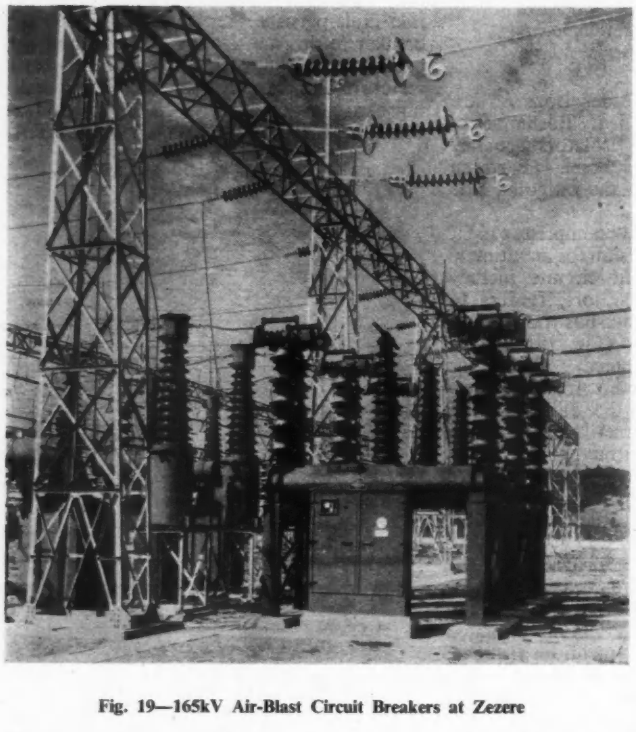


Fig. 19—165kV Air-Blast Circuit Breakers at Zezere

The two generator circuits and the bus-section are controlled by 2400A air-break circuit breakers, remote-operated from the control room. The heavier circuits from the switchboard are also controlled by air-break circuit breakers, but they are of 600A rating and manually-operated. Smaller circuits are fed from metal-enclosed fuse-switch units. The main auxiliaries board supplies the power station, the dam, the settlement and the substation.

In addition, each main generator-transformer set is provided with its own essential auxiliaries board, comprising fuse-switch units and latched-in contactors for the circuits associated exclusively with it. Each essential auxiliaries board is fed by duplicate cables, one from each section of the main auxiliaries board. Certain vital services, such as lubricating pumps, are provided with emergency d.c. pumping sets which are automatically switched on to the battery on failure of a.c. supply. The starting here is initiated by cessation of oil flow, &c.; it is, therefore, independent of electrical functions.

At the substation the auxiliary supply is taken from an 11kV tertiary winding on the 165/66kV inter-bus transformer, and then stepped down to 380V by a 250kVA station transformer. A standby supply is provided from the power station main auxiliaries board. All lighting supplies are taken from the auxiliary boards through three-wire/four-wire lighting transformers to reduce the fault capacity on the lighting circuits and also to avoid the necessity of making the auxiliary boards four-wire throughout.

Controls.—Independent controls are provided at the power station and the substation because, as already stated, the equipments belong to different authorities. The H.E.Z. controls the output from the generators and the C.N.E. the distribution at 165kV and 66kV.

The power house control room overlooks the machine hall. The control board (Fig. 20) is of the conventional vertical sheet steel cubicle form, arranged around three sides of a rectangle, with a desk board in the centre. It is equipped with a full mimic diagram, instruments, controls and alarms for the three main generator-transformer sets, including their associated 165kV breakers at the substation, and for the two auxiliary generators and the bus-section breaker on the auxiliary board. Also controlled from here is the 15kV circuit breaker for the loading resistance. The equipment includes automatic voltage regulators, synchronising, and master frequency indication. A hydraulic control cubicle provides remote control and indication from the dam. Relays and metering are mounted on cubicles housed in separate rooms adjacent to the control room.

At the substation the controls are housed in a building in the switchyard. The control board is of the same general form, being of vertical sheet steel panels, without the desk, and is arranged on four sides of a square. It provides control for all 165kV and 66kV feeders, the inter-bus transformer and the coupler-section equipment. Check synchronising is fitted to all feeder circuits. Relays and meters are again housed separately from the controls.

Protection.—The generator neutrals are each earthed through a voltage transformer shunted by a non-linear resistor. The 165kV and 66kV star points of the transformers are earthed solidly.

The main generators are provided with circulating current protection, together with overcurrent back-up, the latter operated from current transformers in the star point. Overvoltage protection is also provided. Generator earth-fault is limited to the current which can be passed by the neutral voltage transformer. The generator can, therefore, continue to operate with an earth-fault on one phase, but a relay, connected to the voltage transformer, gives an alarm that such a condition exists. Rotor earth-fault also gives an alarm. Balanced voltage protection covers the main transformers, and includes the stub-lines to the substation in the protective zones. The main transformers are fitted with Buchholz relays, and oil and winding temperature indicators and alarms.

The auxiliary generators are protected by circulating current backed up by overcurrent and earth-fault, together with overvoltage relays. The inter-bus transformer is protected by balanced voltage, together with Buchholz, and back-up overcurrent and earth-fault on both sides.

The 66kV feeders are fitted with directional protection. For the 165kV feeders back-up protection only has been provided by the "British Group." The line protective relays were the subject of a separate contract placed by the Companhia Nacional de Electricidade, which is intended to apply to the whole of the Portuguese e.h.v. network. These protective relays, however, in the case of the Zezere substation, were mounted and wired on panels provided as part of the main switchgear contract.

Ancillaries.—Ancillary equipment includes batteries and charging gear at both power-house and substation, and also an automatic telephone exchange.

Power-House Crane.—In the power-house there is an electric overhead travelling crane designed to handle a maximum working load of 260 tons (the heaviest lift is the generator rotor with a weight of about 240 tons) and having motions of main hoisting (two speeds), auxiliary hoisting (20 tons), traversing and travelling. It is operated by four electric motors designed for 380V, three-phase, 50 c/s.

The main hoist controller consists of an enclosed contactor panel operated by a drum

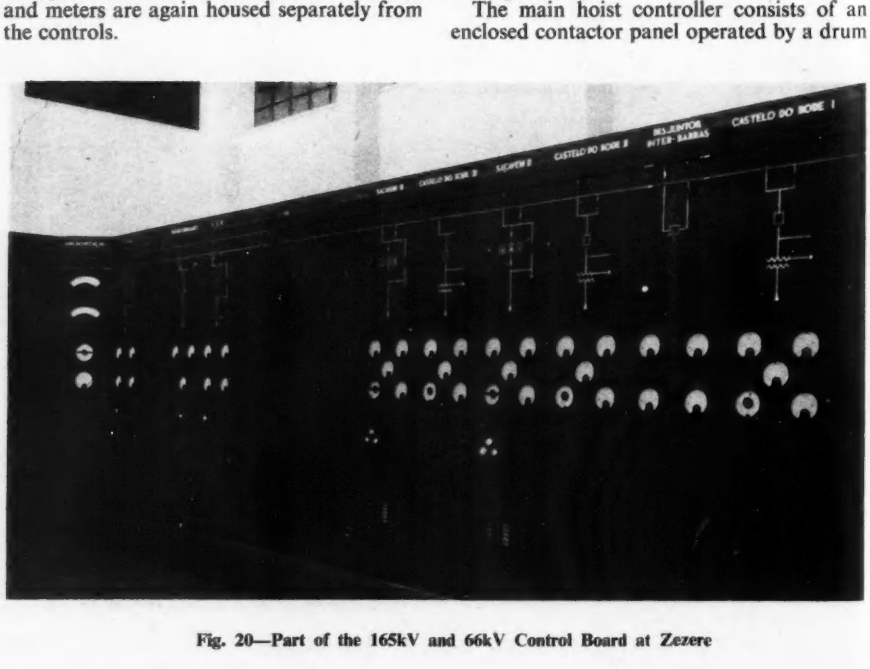


Fig. 20—Part of the 165kV and 66kV Control Board at Zezere

master controller with crank handle. The other controllers are upright air-break drum controllers with crank handles. All controllers have "off" position interlocks and the hoist controllers are suitable for working in conjunction with shunt limit switches to prevent overwinding. Automatic electric brakes are provided; they are operated by a "thrustor" connected in such a way that the brake is released immediately the motor is started and is applied immediately the current is cut off or fails for any reason.

Disperser Valves.—Two disperser valves are installed for operation on the two 3m (9ft 10in) diameter scour culverts, one of which is on each side of the power station. Each valve discharges 150 cubic metres (150 tons) of water per second under a maximum head of 95m (312ft). The energy is effectively dispersed by converting the solid jet into a hollow cone, to avoid erosion to the banks of the narrow gorge and the river bed.

Draught Tube Gates.—A set of draught tube gates is provided for the main turbines, comprising two gates of steel construction 6·4m (20ft 11in) wide by 3·35m (11ft) high with rubber seals and gunmetal guide strips and a by-pass valve located in one gate only. One draught tube gate is also provided for the auxiliary turbines; it is made of timber, 1·53m (5ft) wide by 1·53m (5ft) high. For handling the parts of the disperser valves and the draught tube gates, an electric jib travelling crane, capable of lifting 25 tons, is provided. The motions of hoisting, slewing, and travelling are each operated by an independent motor.

Drainage and Dewatering Pumps.—Two drainage pumps are provided for draining the station pits, each consisting of a vertical centrifugal pump driven by a 12 h.p. electric motor. For dewatering the draught tubes there are two pumping sets, each comprising a vertical pump with a 60 h.p. motor.

Flow Meters.—Three aerofoil flow meters are fitted in the pipes leading to the main turbine valves, each comprising an aerofoil wing of bronze with rustless ball bearings and a set of transmitting flow indicating and recording instruments. Other items of general equipment are purifying equipments for turbine and generator oil and for transformer oil and a testing equipment for transformer oil.

Manufacturers of the Plant and Equipment

The manufacturers of the main items of plant and equipment in the Castelo do Bode power station and Zezere substation, as described in this article, were as follows:—

Main and auxiliary water turbines and inlet valves, main and auxiliary generators, The English Electric Company, Ltd.; main transformers, Metropolitan-Vickers Electrical Company, Ltd.; power station and substation switchgear, Metropolitan-Vickers Electrical Company, Ltd.; disperser valves for scour culverts, The English Electric Company, Ltd.; power station crane and jib crane, Sir William Arrol and Co., Ltd.; draught tube gates, Sir William Arrol and Co., Ltd.; purifying equipment for turbine and generator oil, Alfa-Laval Company, Ltd.; purifying equipment for transformer oil, Streamline Filters, Ltd.; main and control cables, British Insulated Callender's Cables, Ltd., overhead line to substation, British Insulated Callender's Construction Company, Ltd.

(*To be continued*)

"R.M. 60" Marine Gas Turbine

Two medium-life experimental gas turbines, suitable to act as propulsion units for light, high-speed naval craft, have been developed since the war by Rolls-Royce, Ltd. Each engine has a compound cycle and develops about 5400 b.h.p. They are to be installed in the gunboat H.M.S. "Grey Goose" for sea trials and are described below.

SINCE the war Rolls-Royce, Ltd., has been engaged in the design and development, for the Admiralty, of a medium-life experimental gas turbine suitable to be employed as the main propulsion unit of light, high-speed naval craft. Theoretical examination of the problems involved to produce an engine having a wide power range combined with economical low-power cruising resulted in a compound cycle being chosen, and the prototype engine, designated "R.M.60," was ready for running tests in June, 1951. Two of these engines have been built, one has completed shore trials and, after being reconditioned and tested, following 1100 hours' development running, has been installed in the gunboat H.M.S. "Grey Goose." At the invitation of Rolls-Royce, Ltd., representatives of the technical press were able to inspect the second engine on the test bed, shown in our illustration, and to see a static exhibition of the various engine components, and were informed by Mr. A. G. Elliott, the joint managing director of the company, that two additional engines have been ordered by the United States Navy for trial in an escort vessel of 1700 tons displacement.

The "Grey Goose," in which the engines will shortly undergo sea trials, was built by J. Samuel White and Co., Ltd., in 1941, and has a length overall of about 146ft, a 20ft beam and a displacement of 205 tons. This vessel was originally powered by two single-reduction geared steam turbines, each of 4000 s.h.p., taking steam from a single boiler and having a specific weight of 14 lb per shaft horsepower. The gas turbine sets, which replace the original steam machinery, embody aero-engine experience in their design and have been produced to a specific weight of 5 lb per horsepower so that they provide a 50 per cent increase in power, combined with a 50 per cent reduction in weight and a saving of 25 per cent in machinery space. To enable the ship to go astern and to assist manœuvring at low speeds, "Rotol" variable and reversible pitch propellers are to be fitted.

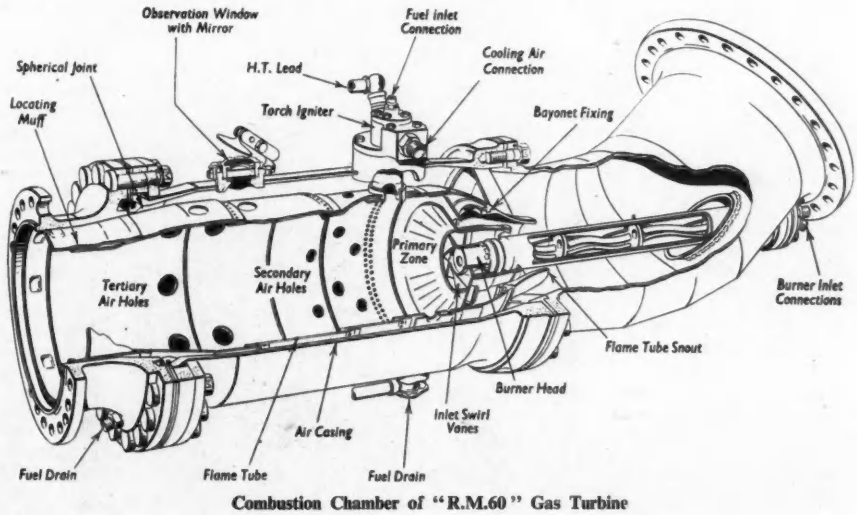
As already mentioned, a compound cycle was chosen to meet naval requirements with regard to power range and low-power cruising, and the line drawing in the supplement facing page 638 gives a diagrammatic arrangement of the engine, together with the gas flow and associated temperatures, pressures and speeds. Low and high-pressure compressors with intercooling between each compression stage was adopted to meet the power range requirement and careful matching of the two compressors, together with the use of an exhaust heat exchanger, has made economical cruising possible.

Air enters the low-pressure axial compressor and passes through port and starboard low-pressure intercoolers, which are sea-water cooled, before entering the first stage of the high-pressure compressor and passing on to the high-pressure sea-water cooled intercooler. After intercooling the air pressure is raised in the second stage of the high-pressure compressor, after which it passes through the exhaust heat exchanger before being admitted to the port and starboard combustion chambers. The expansion of the gases occurs across a single-stage high-pressure turbine, which drives the high-pressure compressor, and then a two-stage mechanically independent power turbine, which drives the propeller through reduction gearing. Further expansion takes place in the two-stage low-pressure turbine, which drives the low-pressure compressor, before the gases pass into the funnel.

The narrow beam of the "Grey Goose," 20ft, and the restricted headroom were the factors causing the engine to be designed as a narrow assembly about 30ft in length, and to allow for the racking and deflection of the ship's hull the engine is divided into two basic units connected to other sub-assemblies by flexible bellows jointed ducting. Possible losses in the ducting between the turbines is avoided by arranging for the power turbine shaft to pass through the rotor bores of the high-pressure turbine and compressor, so allowing for coaxial mounting with the power turbine immediately adjacent to the high-pressure turbine. The power shaft line is raked at an angle of 9 deg. relative to the low-pressure unit. The high-pressure unit, together with the high-pressure intercooler and reduction gearing, the low-pressure unit and the heat exchanger are each mounted on a fabricated steel frame, and the high-pressure and low-pressure unit frames are supported on two parallel engine-room girders. Both the high-pressure and low-pressure units have three-point supports in their respective frames, while the low-pressure intercoolers are independently rubber mounted on the ship's structure. Except for the normal ship's supply services the engine is a self-contained power unit and has a total weight, excluding propeller and shafting, of 13 tons.

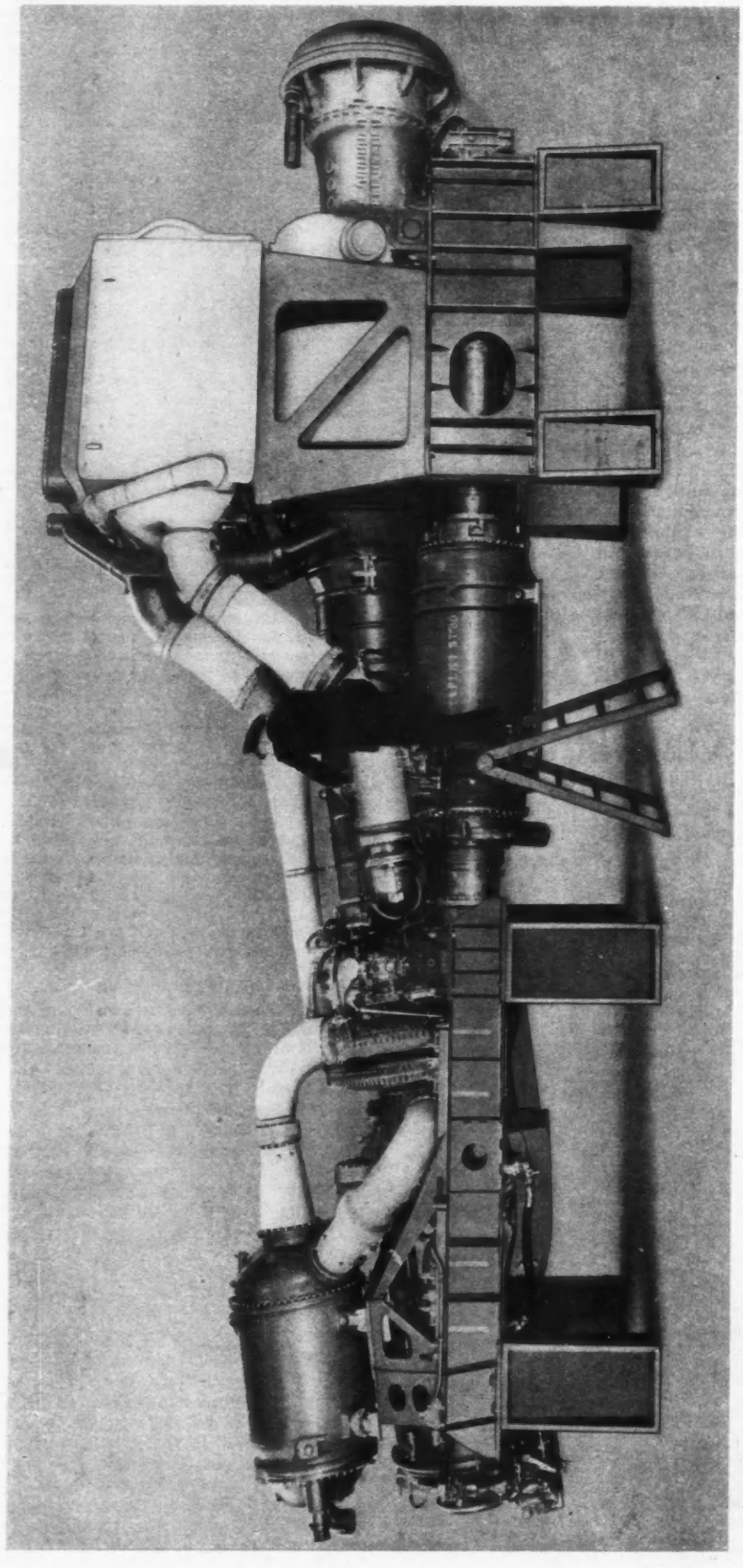
L.P. and H.P. Units

A low-pressure turbine, an exhaust unit and a low-pressure compressor with its discharge casing forms the low-pressure unit, which is



Combustion Chamber of "R.M.60" Gas Turbine

supported in the unit frame by a three-point trunnion system which allows for thermal expansion and hull structural movement. The gas discharge to the heat exchanger is collected in the fabricated sheet steel exhaust unit, which is carried in bellows pattern supports and connected to a flexible plate at the base of the heat exchanger and is placed forward of the two-stage l.p. turbine. There are Hirth couplings between the overhung turbine discs, which are of ferritic steel, have K.E.965 blading and are carried on a hollow steel shaft running in ball and roller bearings. The l.p. turbine, which is a lightly loaded unit, is directly coupled through a floating coupling to the l.p. compressor, which has eleven stages and an aluminium alloy casing carrying inlet and outlet guide vanes. Aluminium bronze is used for the blading and stainless steel for the rotor shaft and discs The axial flow of the air is changed to radial flow, then cascade blading directs the air into two volutes supplying the port and starboard intercoolers. Two automatically operated valves which bleed air from the compressor discharge duct are housed in the discharge casing, at the rear of which is mounted a wheelcase carrying the auxiliary drives to the oil pumps. The compressor is mounted as a cantilever in its discharge casing and arranged to pass through the engine-room forward bulkhead into an air settling space, while a gauze screen protects the inlet and carries a spray nozzle for injecting fresh water to wash salt deposits from the blading.



"RM60" Marine Gas Turbine

One of the more important requirements of the l.p. compressor is that it must operate over an extensive speed range and have a wide range of efficiency with speed. Our diagram of the l.p. compressor characteristic curves shows that this object has been achieved at the expense of about 2 per cent in efficiency at design speed. The efficiencies shown are based on temperature rise measurements and the pressure ratios are based on mean total pressures calculated from static pressures, mass flow and temperature and include the pressure losses in the compressor discharge diffuser, volute and outlet elbow system which account for nearly 1·5 per cent overall efficiency. An outlet velocity of 300ft per second and an inlet velocity of 500ft per second were adopted for the compressor to reduce duct velocities and pressure losses.

A three-point trunnion support system is used for the high-pressure unit consisting of the power and high-pressure turbines, an intermediate air casing, a two-stage high-pressure compressor and the high-speed reduction gearbox, all of which are rigidly bolted together to ensure alignment of the shafting. A single overhung steel disc carrying Nimonic 90 blading and situated in front of a steel twin volute nozzle-box, forms the h.p. turbine, which is connected to the high-pressure compressor shaft through a muff coupling in the intermediate air casing. A single-stage design, with its high blade speed, was adopted for the h.p. turbine, since any gain in efficiency from a two-stage turbine would be more than offset by ducting losses due to the difference in the diameters between the h.p. and power turbines. The small blade height of the h.p. turbine and the narrow ducting into the nozzle guide vanes raised distribution problems which were solved by ducting the hot gas into the turbine through a twin volute entry. The turbine and its entry ducting have an overall efficiency of 85 per cent.

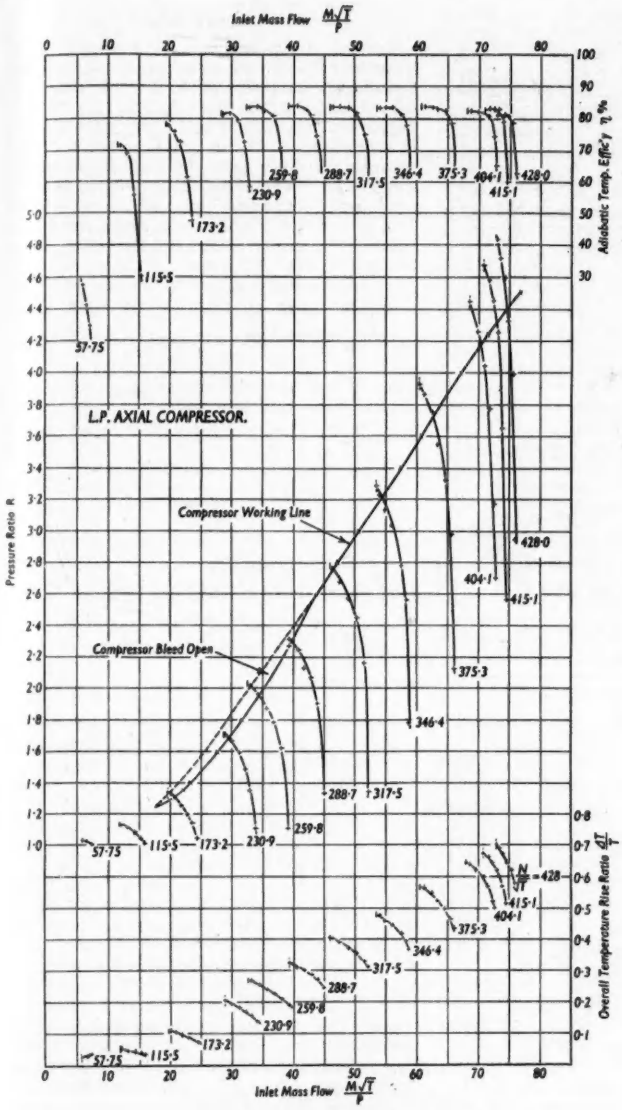
To the forward face of the h.p. turbine casing is bolted the two-stage power turbine having Nimonic 80 blading, which has to operate efficiently over a two-to-one speed variation and has a low exhaust gas velocity so that the duct losses between the power and l.p. turbines are kept low. The peak efficiency is 89·5 per cent. The power drive shaft passes through the hollow h.p. turbine and compressor shafting and has a muff coupling inside the h.p. turbine and compressor shaft coupling.

By adopting this form of construction the turbine unit can be removed without disturbing the auxiliary drives housed in the intermediate air casing. In general, the casings are of aluminium alloy except those for the turbines, which are of heat-resisting steel.

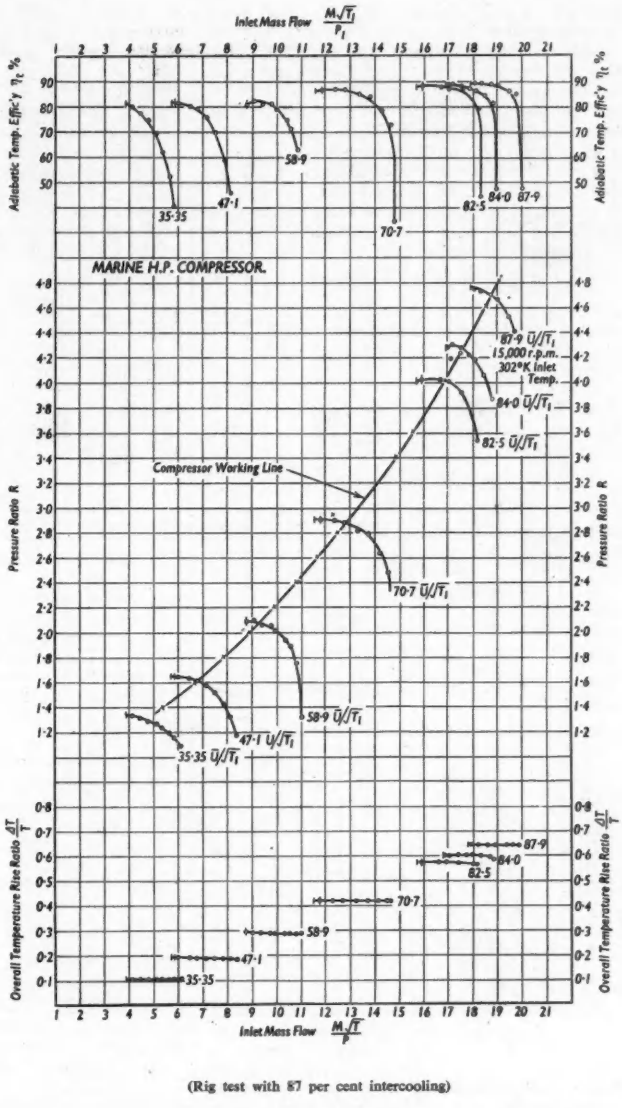
Compressors and Intercoolers

Stainless steel has been used for the compressor impellers, which are fully shrouded and mounted on an articulated shaft. Each carries rotating guide vanes and is surrounded by a stainless steel diffuser ring.

In contrast with the l.p. compressor with its wide efficiency range, the two-stage intercooled h.p. compressor attains peak efficiency at design speed and the characteristics of the compressor, with 87 per cent intercooling, are given in the accompanying diagram. This shows the total pressure ratio/mass flow characteristics for the speed range and gives the temperature rise corresponding to the sum of the separate stage temperature rise measurements, together with the corresponding efficiency. With only 60 per cent intercooling obtained at maximum power, the overall efficiency is less than that shown by the curves. At the design speed of 15,000 r.p.m. the



L.P. Compressor Characteristics



(Rig test with 87 per cent intercooling)

H.P. Compressor Characteristics

adiabatic efficiency of each stage, based on temperature rise measurements, is 80 to 82 per cent, and based on the sum of the separate stage temperature rises the figure of 88 per cent is obtained. If the overall efficiency is based on the shaft horsepower from dynamometer readings the efficiency is 84·5 per cent.

The connecting duct between the turbines is lagged and around this, leaving an air space between, is a light metal cover. Cooling air, from holes in the h.p. turbine casing, flows around the nozzle box and is drawn through the air space by the action of an injector placed aft of the funnel. Air is also drawn in between the l.p. turbine housing and its exhaust unit, and passes out to the ejector through hollow spokes in the turbine discharge annulus. At low power the air to operate the ejector is supplied from automatic bleed valves of the l.p. compressor; they close at the higher powers and a flap valve falls over to connect the ejector to the inlet side of the heat exchanger so that the ejector continues to be operated by the exhaust back pressure.

Both the l.p. and h.p. intercoolers consist of a fabricated steel casing carrying an annular matrix of cupro-nickel tubes and end plates. Sea-water is circulated through the tubes, from aluminium bronze water boxes, and the compressed air is cooled when passing in cross flow between the tubes. In the l.p. intercooler a central dividing plate causes the air to pass twice across the matrix, while the water makes a single pass through the tubes. In contrast, single-pass air flow is used in conjunction with double-pass water flow in the h.p. intercooler. Sea-water circulation is by scoop action, but there is a small engine-driven pump to circulate water through the h.p. intercooler at low forward speeds or when going astern.

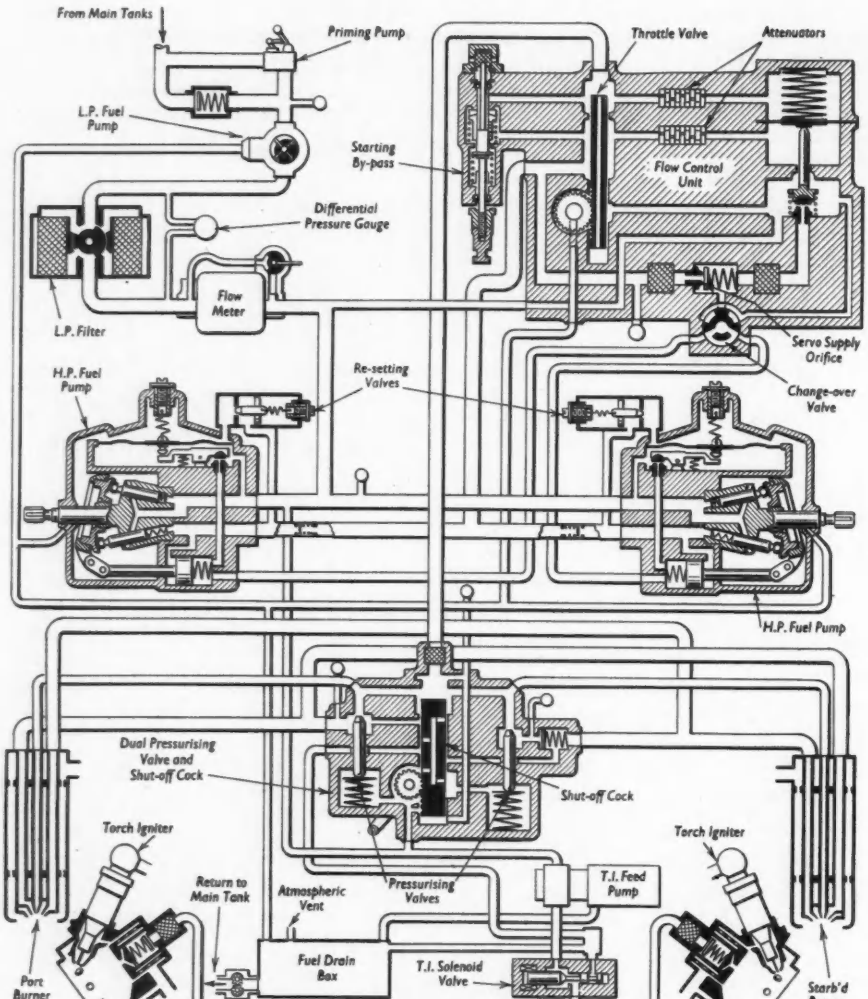
Two matrices constructed of U-shaped stainless steel tubes of ¼in outside diameter and 0·004in thick are carried in the fabricated steel heat exchanger casing. Air enters the upper leg of the U and is discharged through stainless steel collector boxes, fitted with end plates, to the two combustion chambers, while the exhaust gas makes one vertical pass through the matrices. A by-pass channel is provided between the matrices, and through it flow is controlled by butterfly valves. As already mentioned, a flow of cooling air around the turbine casings and inter-turbine ducting is induced by an ejector operated by hot gas ducted from the heat exchanger inlet and at low engine speeds air is ducted through the l.p. compressor bleed valves to the ejector.

The diagram on page 617 illustrates one of the two combustion chambers which follow aircraft practice and have a stainless steel air casing and a flame tube and swirl vane assembly of Nimonic 75 heat-resisting alloy. Each combustion chamber has an axially fitted burner which injects fuel downstream through three concentric metering orifices and is supplied, through separate pipes, with pilot fuel, intermediate fuel, main fuel and air, tapped from the delivery side of the h.p. compressor, for cooling burners and the torch igniters. A torch igniter with fuel atomiser is carried by each combustion chamber, together with a high-tension sparking plug to initiate lighting up during the starting cycle.

The drawing on page 620 shows a diagrammatic arrangement of the fuel system. The burners operate in conjunction with dual pressurising valves which proportion the flow of fuel between the triple orifices. Fuel is injected by two high-pressure plunger pumps driven from the h.p. turbine and having their delivery controlled by varying the stroke of the plungers by hydraulic means through a servo system. A flow control unit incorporates the throttle valve and a manually operated slow running control and also contains the mechanism controlling the servo mechanism. Fuel supply to the main high-pressure pumps is delivered by a vane pattern low-pressure pump through a low-pressure filter and a flow meter, while, during starting, fuel is supplied to the torch igniters through a solenoid-operated shuttle valve by an electrically-driven vane pattern pump mounted on the l.p. intercooler. To shut the engine down the fuel supply is cut off by a high-pressure cock and is recirculated to avoid pressure build up.

Reduction Gearing

The shaft from the power turbine is coupled to the double helical driving pinion of the high-speed gearbox, which meshes with three large driven gears set in clover-leaf formation and location is by a small Michell bearing mounted on the driving pinion. Three flexible layshafts, which incorporate toothed couplings to take up any misalignment due to racking and local deflection of the ship's structure, transmit the drive from the high-speed to the low-speed gearbox, which is bolted to the rear of the h.p. unit mounting frame. The initial alignment of the two gearboxes is obtained optically by telescopes; the fitting of a Rolls-Royce elec-

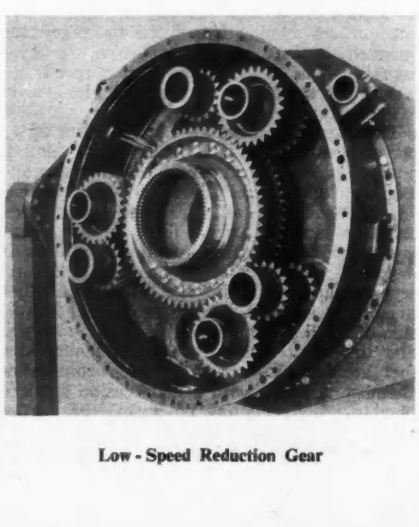


Diagrammatic Arrangement of Fuel System

trical phase-shift power meter in each quillshaft driving the pinions of the low-speed gearbox checks the setting of the layshaft couplings to transmit equal torques, and gives a continuous indication of the total power being transmitted.

Our illustration shows the low-speed reduction gear, which consists of a central bull gear, carried in white metal bearings, and three double helical pinions driven by the layshafts, while provision is made for the fitting of idlers, between the pinions and the bull gear, to give handed propeller rotation in a twin-screw installation. A quill pattern torsion coupling transmits the drive to the propeller stub shaft and provides a measure of flexibility besides reducing the possibility of propeller shaft distortion and axial vibration being transmitted to the bull gear teeth. The forward end of the stub shaft carries the main collar of the Michell thrust bearing, which is housed in the rear panel of the h.p. unit mounting frame, and the rear end forms the front plate of the "Rotol" propeller operating cylinder. The gearbox includes auxiliary drives for the oil pumps and "Rotol" governor unit, and the pump drives are arranged so that the pumps rotate in the same direction irrespective of propeller rotation. As a safety precaution there is a duplicate set of pumps which are electrically driven and are energised at low engine speed by a pressure switch.

Each of the units having independent rotating shaft systems have pressure and scavenge lubricating oil pumps, the pressure pump being supplied from a common oil tank through a dual flow filter, while the scavenge oil is returned to the main tank through a cooler. A differential pressure gauge is fitted across each oil filter, the elements of which can be changed with the engine running. Cyclone breathers keep oil losses, due to high-pressure air leakage, into the bearing compartments of the h.p. unit, to a minimum, and the total oil consumption is estimated to be 2 pints per hour.

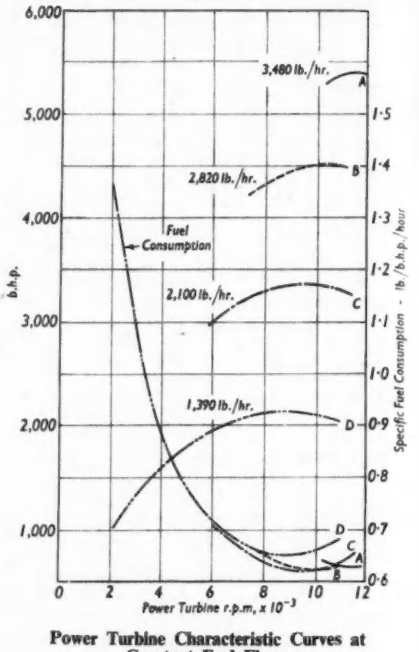


Low-Speed Reduction Gear

Controls

Control of the engine is by a throttle handwheel and four levers, which operate the starting throttle, the propeller pitch, the heat exchanger by-pass and the fuel shut-off cock. To start the engine the h.p. turbine and compressor shafting is rotated by a 40 h.p. electric motor driving through auxiliary gears located in the intermediate air casing and a flame is initiated in the combustion chambers by the torch igniters. Full power is available within three minutes of pressing the starter button and the starter motor cuts out at about 5000 r.p.m.

When starting, the throttle handwheel is fully closed and the starting throttle is set partly



Power Turbine Characteristic Curves at Constant Fuel Flows

open; as the heat exchanger warms up the starting throttle is progressively closed until the engine is idling with both controls at their idling stops. When the h.p. compressor turbine set is idling at 7000 r.p.m. the l.p. set is turning at a very low speed and the automatic bleed valves are open to bleed about 5 per cent of the l.p. compressor discharge. As the main throttle is opened the h.p. set increases speed and the l.p. compressor commences to boost the h.p. compressor inlet, and the bleed valves progressively close until 2200 h.p. is reached, when, with the valves closed, the l.p. and h.p. sets are running at 5000 and 14,000 r.p.m. respectively. At 4700 b.h.p. the h.p. set attains its maximum designed speed of 15,000 r.p.m., then the fuel pump governors come into operation and the throttle may be fully opened. The remaining amount of power, up to the maximum of 5400 b.h.p., is obtained by progressively opening the

TABLE I

Performance Data

Full power rating (at 15 deg. Cent. ambient air and intercooler water temperature)	5400 b.h.p.
Specific fuel consumption (at full power)	0·66 lb/b.h.p./hr
Thermal efficiency (at full power)	21·2 per cent (l.c.v. 10,000 c.h.u./lb)
Maximum gas temperature	827 deg. Cent.
Maximum cycle pressure	265 lb/sq in
Pressure ratio	18 : 1
Overall mass flow	65 lb/sec
Shaft	675 r.p.m.

Component Adiabatic Efficiencies
(Shaft adiabatic quoted at maximum power)

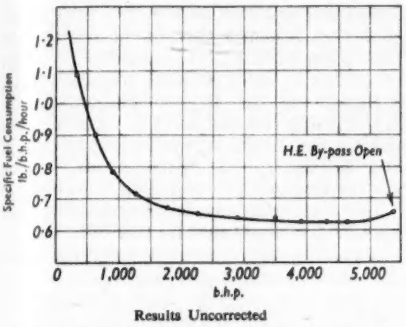
Low-pressure compressor	81 per cent
High-pressure compressor (stage 1)	80 per cent
High-pressure compressor (stage 2)	81 per cent
Low-pressure turbine	88·5 per cent
High-pressure turbine	85 per cent
Power turbine	88 per cent

Thermal Ratios

		Pressure losses
Low-pressure intercooler	0·84	2 per cent
High-pressure intercooler	0·60	1·5 per cent
Heat exchanger (by-pass shut)	0·62	2 per cent (air side)

Cooling Air Bleeds

Low-pressure compressor	4 per cent
High-pressure compressor (stage 1)	2 per cent
High-pressure compressor (stage 2)	3·5 per cent



Initial Specific Consumption Curve with Propeller Law Power Turbine Speeds

heat exchanger by-pass to decrease the gas pressure drop across the heat exchanger matrix and so increase the expansion ratio across the l.p. turbine to speed up the l.p. set to design speed.

There is an interlock between the engine throttle and the propeller pitch controls to prevent the blades being feathered while the engine is developing high power. The interlock is set so that for powers above 600 s.h.p. the propeller pitch is constant at 35 deg., while below this power any pitch can be used; however, at full astern pitch of 45 deg. power can be increased above 600 s.h.p. to a predetermined limit, but must be reduced again before the pitch can be altered. The proximity of the engine working line to the h.p. compressor surge line limits the rate of acceleration and deceleration above 250 b.h.p., so a dashpot device limits the rate of throttle movement. To stop the engine a cock in the high-pressure fuel line is closed and the fuel recirculated, and centrifugal bolt trips are arranged to close the shut-off cock when either turbine exceeds its maximum speed.

In Table I on page 620, there is recorded performance data, component adiabatic efficiencies and thermal ratios. The accompanying graphs show specific fuel consumption plotted against brake horsepower and power turbine characteristics at constant fuel flows.

Cancer Research Work of the Atomic Energy Commission

(By Our American Correspondent)

THE cancer research hospital in Chicago of the Argonne National Laboratory has now been completed and is believed to be the largest facility ever designed and built specifically for the purpose of applying atomic energy to the diagnosis, study and treatment of cancer and closely allied disorders. The cancer research programme of the U.S. Atomic Energy Commission was begun early in 1948 under the stimulus of action by Congress in making the initial appropriation implementing the Atomic Energy Act. In its appropriation for the fiscal year 1948, the Congress made available to the Commission for cancer research work "such sums (not exceeding 5,000,000 dollars) as the Commission believes can be used efficiently without duplicating research work of other public and private agencies." In connection with the authorisation by Congress to engage in cancer research, two significant facts should be noted: (*a*) the Commission's programme is one of research and not clinical treatment (only a limited number of patients are treated), and (*b*) in order to avoid duplicating or repetition of efforts of other Government agencies and private foundations, the programme is concentrated upon the unique tools and products of atomic energy—such as atomic reactors and radio-active isotopes—and their application to cancer treatment. The Commission's programme of research in the study, diagnosis and treatment of cancer essentially falls within three categories: (*a*) investigations being carried out at National Laboratories or major facilities; (*b*) "off-site" studies being supported by the Commission at certain universities, hospitals or research centres utilising unique applications of atomic energy, and (*c*) the distribution of radioactive isotopes for cancer studies. The work under the first part of this programme is conducted at the four major A.E.C. cancer research centres situated at the Brookhaven National Laboratory, the Oak Ridge Cancer Hospital, the Argonne Cancer Research Hospital, and at the Radiological Laboratory at the University of California Medical Centre in San Francisco.

The newest and largest of these four facilities is the Argonne Cancer Research Hospital in Chicago. Built and equipped by the A.E.C., this centre is being operated for the Commission by the University of Chicago. The hospital consists of six floors, a basement and a sub-basement. Two floors are for patient care, providing beds for fifty-six patients. The remainder of the building houses numerous radiation devices and laboratories, including powerful radiation sources. A 2MeV Van de Graaff generator will be used for rotational therapy and for studies of the effects of very high energy X-ray on cancer. A linear accelerator will be used to accelerate electrons to energies up to 50MeV, sufficient to allow them to pass easily through the body. Other equipment will include a rotational therapy machine employing a 1800 curie source of cobalt-60. The 450MeV proton synchro-cyclotron of the University of Chicago already is completed and will be made available for use by the hospital research staff. Standard X-ray facilities and radioactive isotopes also will be available. These sources will enable the hospital to utilise all types of ionising radiation now thought to have possible value in cancer therapy, excepting only pile-generated neutrons. The hospital will be used solely for cancer research; not for the treatment of other diseases, nor for the routine treatment of cancer by methods already established.

The atomic pile at the Brookhaven National Laboratory is being used in the treatment and study of cancer. The line of attack here is to develop a technique of irradiating deep-seated brain tumours, utilising a neutron capture reaction in order to destroy the cancer without damaging healthy tissue surrounding it. The treatment begins with injection of a solution of borate, compounded from boron 10, into the patient's bloodstream. The patient is placed in such a position that the tumour is exposed to a beam of neutrons from the pile. As the neutrons reach the tumour, they are captured by the boron atoms, which break down, emitting alpha particles. It is these alpha radiations which destroy the tumour cells. The response of some of the patients to this treatment has been impressive, although the improvement in all cases has been temporary. Ten patients have been irradiated. All the cases treated at Brookhaven have been considered terminal cases by their physicians. Unfortunately, none of the cases to date was cured, but in the more favourable cases about six months of useful time was added to the patients' life spans. Periods of observation of up to six months have revealed no serious complications resulting from this form of treatment. Before adequate control of tumour growth can be expected, a great deal more information must be obtained on the rate of distribution of the boron through the tumour mass, and further instrumentation must be developed to provide more accurate information as to the total integrated dose given to the tumour.

The Oak Ridge Cancer Unit was developed in co-operation with the Oak Ridge Institute of Nuclear Studies. The hospital contains twenty-eight beds, and the research activities are aimed at exploiting the pile-made isotopes which are immediately available at Oak Ridge. Special emphasis is being placed on studies with isotopes never before used in medicine and on the very short-lived isotopes which cannot be utilised at distances from the source. The Oak Ridge group has actively pioneered in the development of cobalt-60 teletherapy units. These devices using highly active isotope sources, are so designed that a beam of radiation may be directed into the body from the outside, as a form of treatment for certain malignant tumours. Teletherapy has proved beneficial in treating deep-seated cancers. It offers the advantage of requiring relatively small sources, enabling the irradiation to be better concentrated on the tumour mass and reducing the irradiation of surrounding healthy tissue. Cobalt-60 units now are in use or planned for use in many treatment centres throughout the country. More recently the Oak Ridge group has been working on other types of sources for teletherapy, notably cesium 137.

At the University of California Medical Centre in San Francisco, a radiological laboratory has been built and equipped with funds supplied by the Commission. Housed in this laboratory is a 15-ton synchrotron for the treatment of cancer patients. This unit, which is capable of producing a beam of ionising radiation ranging in energy from 5 to 70MeV, has recently been completed, and experiments are now under way on the irradiation of various biological systems. The treatment of patients has not yet commenced, pending the results of these preliminary experiments. The synchrotron is capable of delivering powerful X-ray beams on cancer deep within the body with less dosage to surrounding tissue than is possible with lower voltage equipment. The group at the Radiological Laboratory also has investigated methods of treatment of thyroid cancer by the use of radio-active iodine 131.

In addition to research being conducted at the above facilities, the A.E.C. supports cancer research at various universities and medical schools. These studies involve unique applications of atomic energy developments to cancer, such as the attempts to use the annihilation-of-matter reaction from positron emitters in the diagnosis of brain tumours, the use of radio-active gold in interstitial therapy, and the use of cobalt-60 in needles and seeds in place of the more expensive radium. It is believed that all of these activities, in achieving their objectives in cancer research, will pay dividends in the form of added knowledge concerning the biological effects of ionising radiation. It is too soon as yet to offer conclusions concerning the ultimate part of atomic energy in the problem of the control and cure of cancer. Although a greater variety of bigger and better sources of ionising radiations may not prove to be the final answer to the cancer problem, such sources are proving themselves to be valuable experimental and therapeutic tools. Treatment is limited by the degree of damage which may be produced in intervening and nearby normal tissues. Therefore, it would appear that considerable research is required in advancing methods to concentrate the ionising radiations in cancerous tissues. Eventually, the greatest value of the application of atomic energy to medical and biological problems may well be found in the exploitation for research of radioactive isotopes of the elements which normally make up living matter. In this manner, it is felt that atomic energy is certain to aid in the solution of many problems associated with cancer.

EDUCATIONAL USE OF INDUSTRIAL TELEVISION EQUIPMENT.—One use of industrial television for instructional purposes was demonstrated during the opening ceremonies of the National College of Rubber Technology on November 3rd. A Pye industrial television camera was installed in the rubber shop on the ground floor of the new college and details of processes in rubber manufacture were transmitted pictorially to a 27in Pye monitor set installed in the lecture theatre before an audience of 180. Questions asked by members of the audience were answered through a "talk-back" system and the answers were illustrated by the demonstrator in the rubber shop. All the main laboratories in the College are, we learn, wired for television. The complete equipment for the generation and control of the television image is housed in a small camera case. Only two external connections are necessary: the mains input and either a low-level video output or an r.f. output tunable over the normal B.B.C. channels. The equipment normally comprises a camera with a 1in focal length lens, a camera pedestal and a 14in monitor tube with a stand.

Simplicity of Worm Gearing

By PROFESSOR W. A. TUPLIN, D.Sc., M.I.Mech.E.*

Standardisation of cutters for worm wheels means standardisation of worms. For this reason rational design of worm gearing is simpler than for other kinds of gear. All that is required is a means of estimating the approximate root diameter and lead of the best worm for each application, a few seconds' search in a list for the two standard worms that most closely approximate to the desired values of these dimensions, and a few minutes' calculation to identify the better of these two.

THIRTY years ago no one would have ventured to speak of simplicity in connection with worm gearing. To those outside the circle of specialists simplicity was unthinkable ; to those inside it, no hint of a possible breach in the circumference was mentionable. Since then much more experience has been gained, many more people have gained it, the mumbo-jumbo surrounding worm gearing has diminished in fervour and the manufacture of worm gears, long a matter of routine, is now accepted as metallurgy and machining without magic or mystery.

The pattern of development is typical of what happens to mechanical devices. The first stage is a bright idea for something that will work in some fashion. This stage is either easy or impossible ; either the bright idea occurs or it does not.

The second stage is to make the idea into a commercial proposition. The materials and design that lead to the most economical product must be discovered, usually by repeated trial of many alternatives. In few cases does the first thought stand the test of time ; generally there are many false starts and long journeys up and down false trails. Design procedures are formulated and elaborated to match development with the difference that whilst the ideal product must be simple to meet competition, the same compulsion does not apply to the paper work.

The third stage is reached when, from a welter of hopefully tried alternatives, a particular form of the product emerges as the one showing the greatest overall economy in production and service. Although it has usually been reached by a roundabout path through many complications, this ultimate form is always a fundamentally simple manufacturing proposition, for which equally simple design procedure can be formulated.

Unfortunately, commercial considerations may confuse the issue here. The process of development has been long and costly. Upon the originally simple idea a superstructure of refined technical detail has been erected, patents have been taken out, publicity has hinted of unspecifiable " know-how," sales efforts have been expended to exploit the specialised product and although design and production have resolved themselves into confident routine, it would be anti-climax to admit that in the innermost back room, design proceeds on elemental rule of thumb. That, however, is the case with most well-developed engineering products. Experience has shown pitfalls to be avoided, and, if they are all in fact avoided, performance depends far more on materials and workmanship than on any variations or pseudo-refinements in details of design procedure.

Worm gearing well exemplifies the working of these natural processes. Ancient in concept, it was accepted in the machine age as a device that was convenient where low mechanical efficiency was essential, but the principles of design that sufficed for such service, needed revision in the light of unhappy experiences before worm gears could give high load capacity and high efficiency where high efficiency is kinematically possible. All this has been done and proved by many years of service, the third stage has been reached and it remains only to admit it and to abandon the intermediate complications that now have no useful purpose.

The practical design of worm gears is reducible to a few simple arithmetical processes for selecting a standard worm and calculating the range of number of teeth that may be cut in the worm wheel that will mesh with it at a specified centre distance. The combination of the involute helicoid thread form and the tooth generating principle applied with accurate tools and accurate machines to sound materials ensures a result that cannot be bettered by any amount of fiddling with geometrical details.

A worm is simply a screw and the teeth of the mating worm wheel are cut by a tool that is a multi-toothed counterpart of the worm except for a small increase in diameter so that the roots of the worm wheel teeth shall clear the crests of the worm threads. In one early system the section of the threads by an axial plane closely corresponded in proportions to the Acme screw thread and where lead angles are small this is satisfactory. In a multi-thread worm with lead angle exceeding about 10 deg., the same basis of thread design does not suffice, because sections by planes parallel to the axis, but offset from it, then have forms that markedly differ from that on the axial section in ways that preclude satisfactory action between the worm and the worm wheel.

Incomparably the most satisfactory way out of this difficulty is to use the involute helicoid thread form such as may be produced by a rack-shaped cutter with straight-sided teeth set to generate a helical gear. With blank diameter determined by a simple formula based on the normal pitch of such a cutter and on the lead of the worm, satisfactory thread-forms are produced for any lead from zero to infinity and any lead-angle from zero to a right angle. This scheme is over forty years old. The suggestion that the generating rack should be a British Standard rack is much younger and, being an obvious one, has not immediately found universal favour, but it does, nevertheless, form the basis of a system of standard worms that are unequalled for simplicity and economy both on paper and in manufacture.

Because rapid cutting of the worm wheel teeth demands the use of an expensive gear-cutting hob identical in major dimensions with the worm that is to mesh with the worm wheel, economy requires that worms shall be standardised in the minimum number of designs that will cover the field. The number of schemes that might be used in drawing up a list of standard sizes is infinite, but choice is well restricted when the need is recognised for the closest correlation with existing standards, the utmost simplicity in design calculations and the minimum work in the shops. Perseverance, rather than inspiration, is required in working out all the details of any one of the very few alternative schemes that fill this bill.

Dismissing this task as one for the compiler of a standard specification, one next considers what working instructions such a specification must contain if its purchaser is to be able to use it for design purposes. (No such instructions are contained in British Standard Specification No. 721/1937 (Worm gearing), as it does not standardise either worm gears or tools for producing them.) In particular how does one select the most suitable standard worm to give a specified velocity ratio when meshed with a worm wheel at a specified centre distance ?

Even with velocity-ratio and centre distance fixed, it is physically possible to use a worm of any diameter within a wide range, but,

(1) A worm of small diameter may have excessive shaft-bending stresses and excessive transverse deflection which adversely affects contact-bearing on the teeth of the worm wheel, and

(2) A worm of large diameter may have an unnecessarily high ratio of the sliding speed of the threads on the teeth to the peripheral speed of the worm wheel and the mechanical efficiency is then unnecessarily low.

The desirable number of threads in the worm depends largely on the velocity ratio but is also affected by the severity of the duty and by the centre distance.

It is possible to make calculations in connection with these subjects, but it is more satisfactory to examine details of a large number and variety of worms in successful practice and from them to seek some correlation between root diameters of the worm and the centre distance and between the number of threads in the worm and the velocity ratio. This has been done and some simple design rules emerge. More complicated ones can be found to give some slight apparent gain in accuracy, but complication is not justified on that score, as the object is not to design what might be regarded as the best possible worm for any particular application, but simply to select the best available worm from a standard list.

For velocity ratios higher than about 6 to 1, the root and tip diameters of an average worm are, respectively, about 0·23 and 0·35 times the centre distance. The mean diameter of the worm wheel is thus about 1·7 times the centre distance and the lead of the worm threads is therefore about $1{\cdot}7\pi/$(Velocity ratio) times the centre distance, or $5{\cdot}3\ C/R_g$. For ratios lower than about 6 to 1, larger worms are required, to avoid mid-depth lead-angles over 45 deg., this being usually regarded as a desirable upper limit, at least where the worm normally drives the wheel.

In principle, therefore, the selection of a suitable worm from a standard list is simply the discovery of a worm of root diameter and lead approximating to two easily calculable quantities. In practice the calculation of those quantities must take account of the range of number of threads that may reasonably be considered for any application, but the essential procedure is unaltered and it involves no concept or terminology peculiar to gearing. This is important as the average engineer is not interested in gearing for its

Notation

C—Centre distance of gears in mesh.
d_a—Tip diameter of worm.
d_r—Root diameter of worm.
D_a—Outside diameter of worm wheel. (A satisfactory rule is that $D_a = D_t + 0{\cdot}4\ p_n$).
D_t—Throat diameter of worm wheel.
L—Lead of worm threads.
p_n—Normal pitch of standard rack conjugate to threads.
R_v—Velocity ratio.
t—Number of threads in worm.
T—Number of teeth in worm wheel.
w—Working depth of thread (British Standard makes $w = 0{\cdot}636\ p_n$).

* Professor of Applied Mechanics, University of Sheffield.

own sake, but wishes to know what dimensions to place on his drawing, and the less trouble he has in finding them the better is he pleased.

Solution of General Design Problem

Given R_g (with a few per cent tolerance) and C, to select the most suitable standard worm and to determine the manufacturing dimensions of the worm wheel.

Normal slide-rule accuracy suffices for the following procedure.

1. t = nearest whole number to $40/R_g$.

This is for general purposes. For high-speed or light loading, or to avoid inconveniently coarse pitch, t may exceed this by 1 or 2.

Where high load capacity is required, or to avoid inconveniently fine pitch, t may be 1 or 2 less than this (although, of course, never less than unity).

2. T = nearest whole number to $R_g t$ but avoiding any integral multiple of t.

3. $d_r = C\left(0{\cdot}1+\frac{5}{T}\right)$, or $\frac{C}{R_g+1}(2-0{\cdot}08\,R_g)$, whichever is the greater — approx.

4. $L=\pi(2C-d_r)\frac{t}{T+3}$ approx.

A list of worms presented in order of lead for each number of threads readily shows which ones have values of d_r and L approximating to those determined by (3) and (4). In the following, d_a, L and w refer to the worm tentatively selected for further examination.

5. $D_t=2C-d_a+2w$

6. T must lie between $\frac{\pi t}{L}(D_t-0{\cdot}75w)$ and $\frac{\pi t}{L}(D_t-1{\cdot}75w)$.

If this range contains an acceptable value of T (remembering the tolerance on R_g and the need for avoiding any integral multiple of t), then the worm concerned may be adopted ; otherwise another worm must be tried.

This procedure applies with any worm thread form that is not sharp crested or undercut and has a normal pressure angle of about 20 deg. at mid-depth. The only difficulty that can arise is the absence of any available hob corresponding to a worm that approximates to the required lead and root diameter. If a hob is available, then design may be based on its use ; if not, then a standard design of worm is found in a rationally constructed list.

Whatever system of standard worms may be introduced for worm gearing (and there is no British Standard as yet) the scrapping of existing hobs cannot be contemplated and so the selection procedure used must be applicable to any reasonable worm for which a counterpart hob exists. In the example given below, the listed worms are British Standard helical gears except that the standard generating cutter (of normal pitch p_n) is sunk into the blank to a depth $0{\cdot}7\,p_n$ instead of $0{\cdot}716\,p_n$. The thread thickness is $0{\cdot}557\,p_n$ at distance $0{\cdot}4\,p_n$ from the crest.

Example.—(Linear dimensions in inches ; slide rule calculation suffices.)

To determine the manufacturing dimensions of worm gears to give a velocity ratio of about 8·5 (±5 per cent) and to work at a centre distance of 11in.

1. $t=40/8{\cdot}5=4{\cdot}7$ say 5.

2. $T=8{\cdot}5\times5=42{\cdot}5$.

Table I.—*Part of List of Standard Worms with Five Threads*

(Sixty worms in complete list for $p_n=1$ to $p_n=1{\cdot}875$in). Working depth $=0{\cdot}636\,p_n$.

Lead	Root diameter d_r	Tip diameter d_a	Axial Pitch p_a	Normal Pitch p_n	Minimum worm face f_w	Maximum wheel face F_w	Lead† angle
							Deg. min.
6·50	2·393	3·860	1·30	1·0472	5·2	2·7	33 30
6·60	2·972	4·548	1·32	1·125	5·3	3·0	29 15
6·65	3·722	5·384	1·33	1·1875	5·3	3·4	27 20
6·90	2·009	3·209*	1·38	1·000	5·5	2·3	40 20
6·90	3·236	4·898	1·38	1·1875	5·5	3·4	31 0
7·00	2·559	4·133	1·40	1·125	5·6	2·8	33 40
7·00	3·918	5·668	1·40	1·250	5·6	3·5	25 0
7·25	1·991	3·352*	1·45	1·0472	5·8	2·5	41 0
7·30	3·350	5·100	1·46	1·250	5·8	3·3	28 55

* Topped working depth $0{\cdot}586p_n$: height setting of caliper $0{\cdot}35p_n$ † At mid-depth.

3. $d_r=11\left(0{\cdot}1+\frac{5}{42{\cdot}5}\right)=2{\cdot}4$ (approx.)

or $\frac{11}{9{\cdot}5}(2-0{\cdot}08\times8{\cdot}5)=1{\cdot}53$ (approx.)

The larger value 2·4 is used.

4. $L=\pi(2\times11-2{\cdot}4)\frac{5}{42{\cdot}5+3}=6{\cdot}77$ (approx.)

From this list two standard worms are seen to approximate to the desired dimensions.

(*A*) $L=6{\cdot}50$ $d_r=2{\cdot}393$
$w=0{\cdot}636\times1{\cdot}0472=0{\cdot}666$.

(*B*) $L=7{\cdot}00$ $d_r=2{\cdot}559$
$w=0{\cdot}636\times1{\cdot}125=0{\cdot}715$.

Trying (A)

5. $D_t=2\times11-3{\cdot}860+2\times0{\cdot}666=19{\cdot}472$.

6. T lies between
$(19{\cdot}472-0{\cdot}75\times0{\cdot}666)\pi\times5/6{\cdot}5=45{\cdot}8$.
and $(19{\cdot}472-1{\cdot}75\times0{\cdot}666)\pi\times5/6{\cdot}5=44{\cdot}3$.

Hence this worm limits T to the value 45, which, being an integral multiple of t, is undesirable.

Trying (B)

5. $D_t=2\times11-4{\cdot}133+2\times0{\cdot}715=19{\cdot}297$.

6. T lies between
$(19{\cdot}297-0{\cdot}75\times0{\cdot}715)\pi\times5/7{\cdot}0=42$.
and $(19{\cdot}297-1{\cdot}75\times0{\cdot}715)\pi\times5/7{\cdot}0=40{\cdot}4$.

Hence this worm permits $T=42$, which affords an acceptable velocity ratio.

The complete list of manufacturing dimensions of worm gears that meet the specification is :

Worm	Worm wheel
$t=5$.	$T=42$.
$d_a=4{\cdot}133$.	$D_t=19{\cdot}297$.
$d_r=2{\cdot}559$.	$D_a=D_t+0{\cdot}4\,p_n$.
$L=7{\cdot}00$.	$=19{\cdot}297+0{\cdot}4\times1{\cdot}125$.
$p_n=1{\cdot}125$.	$=19{\cdot}750$.
$f_w=5{\cdot}6$ (minimum face width).	$F_w=2{\cdot}8$ (maximum useful face width).

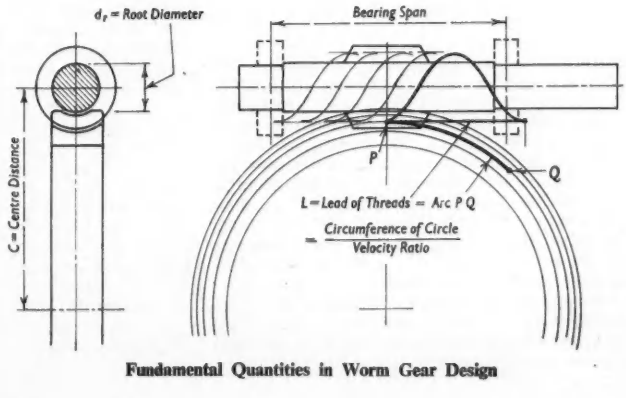
The apparently irregular distribution of leads and root diameters in Table I arises from the fact that the worms have tip diameters that are standard multiples (2·9, 3·3, 3·7, &c.) of the standard pitches listed in B.S. 436/1940, and two worms of common number of threads and nearly equal leads may have markedly different diameters. This variety of diameter for a given normal pitch and number of threads is necessary to cover all reasonable requirements.

In every case the threads as cut are conjugate to the B.S. rack of the normal pitch specified and the thread thickness is reduced by grinding to the standard amount ; if the threads are not to be ground, they are cut appropriately deeper. The worms conform in every possible way to British Standards for spur and helical gears and their manufacture therefore makes maximum use of equipment that either exists or that will have the widest possible utility if made for the particular job.

A method of determining a rational series of standard worms was described in The Engineer for October 24, 1952. A method of selecting the appropriate standard worm for any application was also described in the same article in the same terms. In using such a system, however, there is no need to consider, or even to know, how the list of standard worms was devised and with the mind free in this respect, the problem may be approached with advantage from a different direction. The method described above is in principle what has always been used by worm gear designers intent on employing existing tools to the best advantage. Apart from its elemental simplicity, the method has the advantage (to the engineer of practical mind) of concentrating immediately on the fundamentally important dimensions of the lead and the root diameter of the worm ; for any specified centre distance and ratio, the best values of these dimensions are about the same whatever number of threads may be adopted. The actual process of selecting the worm involves no calculation, but simply running one's eye over half a dozen lines in two parallel columns of figures until a combination is found with about the right lead and the right root diameter. Application of (5) and (6) then shows what numbers of teeth may be cut in the worm wheel that will mesh with any particular worm at any specified centre distance.

The method described here appears to reduce this particular design problem to the utmost simplicity and directness, but suggestions are invited for any alternative that makes an even smaller demand on the non-specialist seeker for standard worm gears. The calculation of every dimension necessary in manufacture is shown. Nothing is calculated that is not used directly in manufacture. No use is made of any concept unfamiliar to the average engineer who has made no special study of gearing.

Given a rational list of standard worms, and rational instructions for its use, it is easier to design worm gearing than any other type of toothed gear.



Fundamental Quantities in Worm Gear Design

Rubber Suspension for Railway Bogies

WE have received particulars of experiments now being carried out by the London Transport development division of the department of the chief mechanical engineer for railways with various kinds of rubber suspension for bogies of both tube and surface line cars. The object of these experiments is to determine the practicability of suspending the whole bogie on rubber, and so bring about a reduction in maintenance costs by eliminating all wearing parts, such as rubbing plates, hanger pins and bushes, as well as the steel springs. Such a form of suspension, it is considered, would do much to reduce, if not eliminate, the running noises resulting from conventional bogie suspensions, particularly in tunnels.

The first experiment was carried out in connection with bolster suspension. The standard arrangement—see (*a*) Fig. 1—consists of a spring plank hung by means of four hangers, two at each end. The upper ends of the hangers are connected to the bogie side frame and the lower ends to the spring plank, which carries helical springs at each end for supporting the car body through the centre pivot. To stabilise the car body for side oscillation the hangers are inclined 8 deg. from the vertical.

The experimental rubber-suspended bolster —see (*b*) Fig. 1—takes the form of two rubber packs at each end of the bolster. By inclining these rubber packs inwards from the top towards

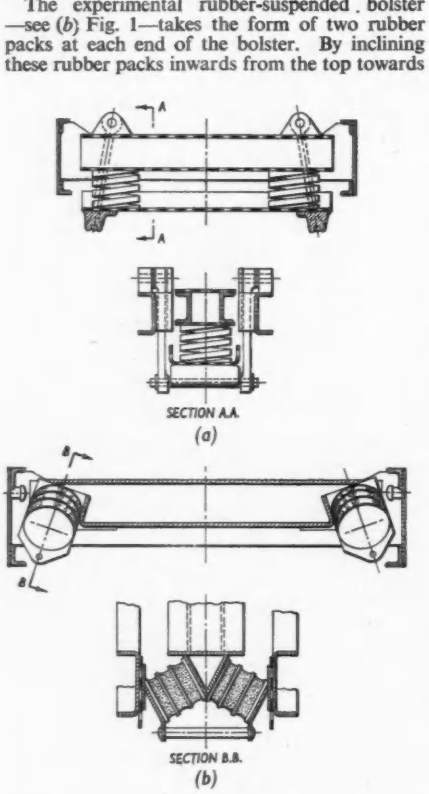


Fig. 1—Standard and New Forms of Bolster Suspension

the centre of the bogie and outwards at the bottom longitudinally it is possible to allow in one arrangement for all the loads taken by the bolster, i.e. the vertical load from the car body plus passenger weight, the longitudinal loads from traction and braking, and the transverse loads from side oscillations. With this arrangement rubber is used in shear as well as compression. A District Line trailer car, fitted with this suspension, was put into passenger service in October, 1947, and has run satisfactorily for the past six years.

An alternative design of bolster was produced, with the rubber packs located outside the bogie frame, the car body being mounted directly on the rubber through vertical struts. This method of suspension eliminated the usual form of bogie centre pivot bearing, as the weight of the car body was carried on the struts which, being inclined, provided a restoring force when they were moved out of centre by the swing of the bogie on curves. When this form of bolster suspension was applied to a tube stock bogie it was not possible to provide the usual shoe beam arrangement for carrying the collector gear, and it was therefore necessary to mount the gear on the bogie frame and provide a compensating device to allow for bogie deflection. This design was tried out on a trailer car on the Piccadilly Line, but under certain conditions of track and curvature the riding qualities were found to be inferior to the previous arrangement, and the design was withdrawn.

Attention has also been given to axlebox suspension, for a suitable design of rubber suspension, used in conjunction with a suitable bolster design, would result in the complete bogie being rubber suspended, and all the present suspension wearing parts eliminated.

The standard system of suspension is shown at (*a*) in Fig. 2. The axlebox is carried in hornguides and both the hornguides and the sides of the axlebox are fitted with manganese liners. The axlebox supports the bogie by a laminated spring carried off the bogie side frame through auxiliary springs and hangers. The centre of the spring sits on top of the axlebox, the buckle of the spring fitting into a suitable recess in the top of the box. Adjustment for wheel wear is made by screwing up or down the nuts on the auxiliary spring hangers.

Several designs of rubber axlebox suspension were considered, but found to be impracticable, partly due to the high cost, but mainly owing to the size of the rubber unit necessary to carry the loads concerned.

In conjunction with Metalastik, Ltd., a design was evolved using chevron or vee section rubbers bonded to suitably shaped plates. This design, being compact, can be located in line with the centre of the axlebox bearing in a very simple manner, as shown at (*b*) in Fig. 2. The whole of the axlebox, complete with the chevron mountings, is placed in a yoke casting bolted to the bogie side frame. To allow for adjustment for wheel wear the yoke is pivoted at one side and bolted through slots at the top and opposite side. A screw adjustment is provided so that the yoke, when slacked off from the bogie frame, may be raised or lowered.

With this design the side frame deflection was limited to ½in, as it was considered that to give a greater deflection would have complicated the design, and in any case the bolster rubbers could, if required, be given increased deflection to compensate for the reduced deflection of the side frame.

Following experimental test running, a car set of this design was fitted to a pre-1938 tube stock trailer car, which had already been fitted with the rubber bolster described above for service trials. The tests showed that this type of axlebox suspension behaved very satisfactorily, vibrations due to rail joints being noticeably damped out. In the normal way, with the standard form of laminated spring suspension, the spring cannot respond quickly enough to absorb rail joint vibration.

This new axlebox assembly, therefore, greatly reduces the dead load impacts on the bearings as well as on the axle. It is also considered that the high-frequency vibration to which an axle is at present subjected, due to the greater rigidity of roller bearings, which are now standard fittings on the axleboxes used on London Transport stock, will be damped out. It has been suggested that these high-frequency vibrations may be responsible for incipient fractures of axles.

From the experiments and trials carried out it is considered that the best arrangement is the design of bolster shown in Fig. 1 (*b*), together with the chevron axlebox suspension shown in Fig. 2 (*b*). A further set of these axlebox suspensions has now been fitted to a District Line car

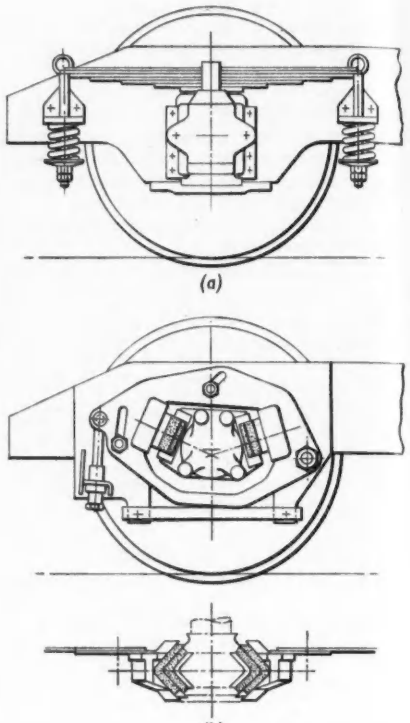


Fig. 2—Rubber Suspension for Axleboxes

so that both axlebox and bolster suspension on one surface line car can undergo extended running tests in passenger service.

We are informed that whilst an accurate appreciation of the financial aspects of these assemblies has yet to be made, depending on the life of the rubber units, a preliminary investigation at a time when price levels were high indicated that the cost per bogie was approximately £50 more than for the standard arrangement. Based on the past six years' experience with bolster rubbers, it is anticipated that the life of the rubber units will be of the order of ten years, if not longer, and on this assumption the saving in maintenance would more than compensate for the extra initial cost.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

SYMBOLS FOR USE ON FLOW DIAGRAMS OF CHEMICAL AND PETROLEUM PLANT

No. 974 : 1953. Price 3s. 6d. Since this standard was originally published in 1941, several other standards for graphical symbols in branches of engineering allied to chemical engineering have been issued, and certain discrepancies between corresponding symbols necessitated a revision.

The committee charged with the revision, under the authority of the Chemical Industry Standards Committee, took into consideration the following British Standards :—B.S. 1553, "Graphical Symbols for General Engineering," Parts 1, 2 and 3, and B.S. 1646, "Graphical Symbols for Instrumentation."

In addition certain British Standards, which, though not yet issued, had reached the final proof stage, a series of symbols submitted by the Ministry of Supply, and others used by various industrial organisations were reviewed. Those considered suitable were adopted or appropriately modified. In its selection the committee proceeded on the principle that, in order to keep the number of basic symbols to a minimum, only those symbols most necessary should be adopted, reduced to their simplest form, and be sufficiently pictorial to enable the units of the plant so represented to be readily recognised. The committee has endeavoured to avoid the use of any symbol which might be identified with a proprietary article. Symbols are intended to indicate the function of a unit of plant, although they may differ in shape from the form of construction of various units all fulfilling the same purpose.

Relay for Automatic Power Factor Correction

A RELAY for the automatic switching of static condensers for power factor correction has been developed by Chamberlain and Hookham, Ltd., Birmingham, a subsidiary of the General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. The relay is designed to determine the lagging reactive component of the load and to switch in the appropriate number of condensers to raise the power factor to the predetermined level. This relay provides up to ten steps of condenser switching and its sensitivity is adjustable, so that good use can be made of the various advantages accruing from power factor improvement, such as electricity tariff concessions and increased load carrying capacity of the consumer's cables.

As can be seen from the accompanying diagram the "Bpf" relay consists of two correlated parts : the first is an induction pattern mechanism sensitive to reactive volt-amperes, and the second is a switching unit, driven by a reversible motor. The reactive volt-ampere element operates on the same principle as the induction watt-hour meter and consists essentially of two electro-magnets between which a pivoted aluminium disc is free to rotate. The current and voltage coils are connected into the load circuit in such a manner that, assuming balanced load and unity power factor, the voltage applied to the voltage electro-magnet is lagging 90 deg. behind the current flowing through the current coil. Under these conditions no torque is developed on the disc and it remains stationary under the influence of a hairspring. When, however, the load is inductive the current lags and becomes more nearly in phase with the voltage applied to the voltage electro-magnet so that a forward torque is developed on the disc. Similarly, if the load is capacitative the current leads and becomes more nearly in anti-phase with the voltage applied to the voltage electro-magnet so that a reverse torque is developed on the disc. Hence the deflection of the disc depends upon the sign, as well as the magnitude, of the reactive volt-amperes present in the load. Two permanent magnets provide the necessary damping. A moving contact is fixed to the disc and moves between two adjustable contacts which are connected to the outer ends of the voltage winding *A* of the switching unit reversible motor.

The switching unit motor is also constructed on the same lines as an induction watt-hour meter, having two electro-magnets between which a pivoted copper disc is free to rotate. Its voltage winding is centre tapped, the mid-point connection going to one side of the voltage supply. The coil receives its energisation via the adjustable contacts on the reactive volt-ampere element and from the connections shown in the diagram it is clear that only half of the coil can be energised at any one time, the direction of current flow through the coil depending upon which end of the coil is connected. The second electro-magnet on this motor is energised from a secondary winding on the voltage electro-magnet of the reactive volt-ampere element and remains permanently energised. It follows that the reversible motor will start up when the reactive volt-ampere element moving contact has been deflected sufficiently to touch one of the adjustable contacts, and the direction of rotation of the motor will depend upon which adjustable contact has been reached, i.e. the direction of rotation of the reversible motor depends upon the sign of reactive volt-amperes in the load circuit.

The reversible motor is connected via a train of gears to a contact-making device which progressively closes or opens a series of circuits depending upon the direction of rotation. These heavy-duty contacts (up to ten, as numbered in the diagram) can be used to operate contactors for altering the number of power factor correction condensers connected to the load circuit. Thus, the switching unit will continue to adjust the number of condensers until stopped by the centralisation of the moving contact on the reactive volt-ampere element when the required power factor is obtained.

A plug bridge is mounted directly above the electro-magnets ; it may be removed or inserted into the required setting by hand, adequate spring pressure being applied to the contacting surfaces to ensure good contact. The standard plug bridge settings are 4 per cent, 12 per cent and 20 per cent of the nominal full load VA value of the relay (obtained by multiplying the voltage and current coil ratings). When the plug is withdrawn the highest setting is automatically selected and there is no possibility, therefore, of open circuiting any of the associated current transformers.

The adjustable contacts on this unit are independently movable and each is locked to the contact carrier by a knurled insulating knob which must be slackened off by the fingers prior to adjustment. An index attached to each contact is associated with a single scale calibrated in units up to four on each side of a central zero. The readings on this scale are multipliers which must be applied to the selected plug setting ; thus with the plug in the 4 per cent position, contact settings up to 16 per cent in either direction are possible. Similarly, the 12 per cent plug position can be used to give settings up to 48 per cent in either direction, and the 20 per cent plug position can be used to give settings up to 80 per cent in either direction.

From the foregoing description it will be seen that the reactive volt-ampere element is called upon to close one of two light-duty contacts, the purpose of which is to influence the direction of rotation of the reversible motor on the switching unit. By this means high sensitivity is possible on the reactive volt-ampere element, while robust heavy-duty contacts can be operated by the ample power available from the reversing motor.

The switching unit of the "Bpf" relay has large contact gaps, heavy contact pressure and massive contacts, and, therefore, is equally suitable for d.c. or a.c. installations. It will be seen from the illustrations that the gaps are always accessible for inspection. Furthermore, the overall size of the relay has been considerably reduced compared with equipment previously obtainable.

Attached to the heavy-duty contacts at each end of the contact bank is a light-duty limit switch which interrupts the supply to the upper electro-magnet, thus preventing further rotation of the disc in that direction. Reference to the diagram

Power Factor Correction Relay with Cover Removed

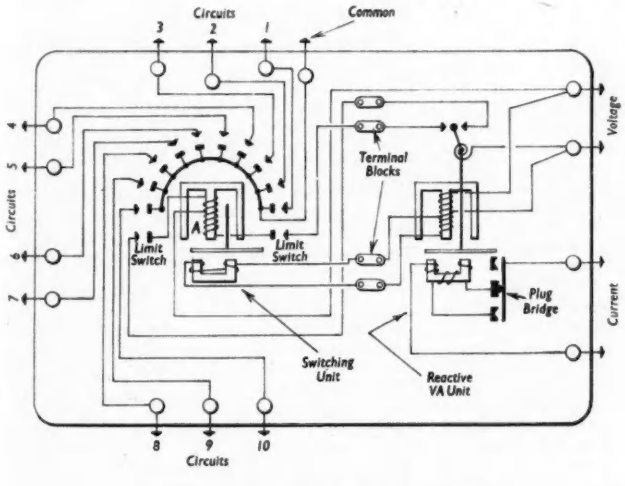


Diagram of Power Factor Correction Relay

Horizontal Form of Power Factor Correction Relay

shows that the limit switches are included in the connections between the adjustable contacts and the ends of the reversing coil, thus allowing the motor to be restarted in the reverse direction when required.

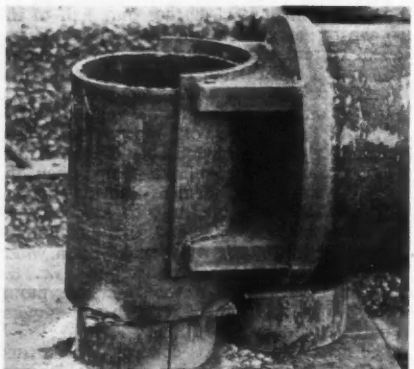
The instrument is available in various forms : the two elements of the relay can be mounted side by side in a horizontal case, as illustrated, or one above the other in a vertical case. In each instance the interconnections between the two elements are carried through small terminal blocks mounted on the base so that one element can be easily removed without disturbing the other, should the need arise. Projecting and flush pattern cases are available for both the horizontal and the vertical layout. The cases are made of cast aluminium finished in black enamel and are specially designed to ensure that removal will not cause dust to fall into the movement.

Tubular Steel Factory

We were invited last week to see the new factory of Tubewrights, Ltd., at the Kirkby Trading Estate, Liverpool. This factory will be used for the fabrication of the company's tubular steel products, and is itself built of welded tubular steel structural elements.

In general conception, the structure is not unlike the tubular steel factory which was described in our issue of October 30th last. The main shop covers 130,000 square feet, being 360ft square with six intermediate 40ft bays and two end bays of 60ft each. The roof trusses are carried on lattice girders which span 120ft. There is also a bay for handling incoming materials which covers an additional area 60ft by 185ft. One requirement of the new building was that production arrangements should be as flexible as possible. Thus, the main columns are 120ft apart, to give as little interruption as possible to the floor area. Also, the welding equipment is to be carried in the roof trusses, above the bottom chord level. For this reason, " butterfly " trusses have been used, so that the ridge of the roof occurs above the column line, at the top chord of the 120ft girders, and the valleys are at the mid-span of the trusses. The bottom chords of the trusses abut on to the bottom chord of the lattice girder, or on to the columns, and the space above them serves to house the welding sets and various other services.

The method of erection, with " cup " bearings for the girders and trusses, was the same as for the factory we described before. But in this case the heaviest lifts were the 120ft girders, which

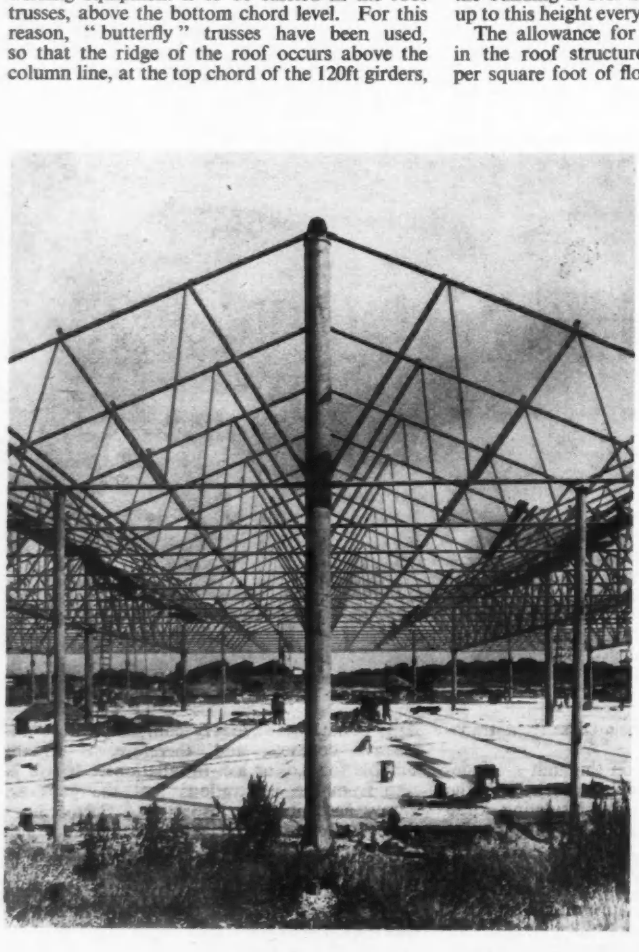


Main Column Cap Assembly

weighed 6½ tons each and were lifted by two mobile cranes. The factory is shown under construction in the illustration herewith; the butterfly trusses were erected and welded into position, and the last member of each truss—that is, the diagonal member between the junction of the column and the bottom chord of the truss, and the first panel point on the top chord, was welded on after erection. The eaves height of the building is 17ft and there is clear headroom up to this height everywhere.

The allowance for conveyor and plant loads in the roof structure was equivalent to 20 lb per square foot of floor area. The columns are therefore rather heavily loaded, and are reinforced with stiffening rings at the bottom chord level. The cap assembly at the top of a column is shown in the second illustration. The columns are 16in in diameter and weigh about 1 ton each. For this building, the fabrication of the various elements was carried out on the site. The total weight of steel is 415 tons, corresponding to 6½ lb per square foot of floor area, which is estimated to be approximately 40 per cent less than would be required for a conventional bolted or riveted rolled steel structure.

It is expected that, at first, the production of the new factory will be at the rate of about 700 or 800 tons of fabricated tubular products per annum, but with double-shift working, and with an extension which is envisaged, production could rise to ten times that amount. The consulting engineer for the factory was Mr. T. Bedford ; fabrication and erection of the steel frame was carried out by Tubewrights, Ltd., themselves.



Erection of Steelwork

Parallel Operation of Privately Owned Generating Plant

A fifteen-page handbook, entitled " Technical Considerations on the Parallel Operation of Privately Owned Generating Plant " has been issued by the British Electricity Authority. It was prepared by the B.E.A. and the Area Boards in association with the Federation of British Industries and the National Union of Manufacturers, which have approved the technical considerations it sets out, and is designed for use by the staffs of the Boards as a basis for guidance to users of private generating plant when the parallel running of such plant with the public supply system is contemplated. Publication of the handbook recalls the announcement by the B.E.A. in January of this year that the Electricity Boards would implement the Ridley Committee's recommendation that restrictive conditions in old contracts on the use and installation of private generating plant should be abandoned. It was then explained that, if any consumer desired to use private plant and such use would contravene the provisions of his agreement with the Electricity Board concerned, the Board would be prepared to enter into a new contract which would reflect the costs of connecting and supplying the consumer, while leaving him free to use the private plant as he might wish.

The B.E.A. and the Area Boards are naturally concerned that parallel running should in no way jeopardise either the public supply or the private supply within a factory, and that it should not introduce hazards to the Boards' or consumers' operating staffs. Accordingly, while the handbook emphasises that every effort should be made to simplify parallel operating procedure as much as possible, it stresses the need of proper technical arrangements to avoid breakdown of either public or private supply and to provide adequate protection of staffs.

It is pointed out that, when privately owned generating plant is operated in parallel with an Area Board's system, that private plant runs, in effect, as part of the system. Since the Area Boards must comply with the various statutory regulations governing the supply of electricity, it follows that the privately owned plant operated in parallel must comply with the relative provisions of these regulations. The handbook goes on to say that experience shows " that an appropriate measure of safety can only be achieved by adhering to recognised rules and it will therefore be necessary for appropriate rules to be complied with by the parties concerned." Rules for ensuring safety of personnel are given in an appendix to the handbook. The body of the text deals with the requirements for the parallel operation of either synchronous, asynchronous or d.c. generators, and there are sections on control of power factor, operational control, protective gear, neutral earthing arrangements, switchgear rating and short circuit duty.

Hydro-Electric Works in Switzerland

The hydro-electric works now being carried out in Switzerland in order to increase the electrical resources of the country, include a major scheme in the valley of the River Dranse. The main element of the scheme will be a dam 775ft high, the Mauvoisin dam, of the arch vault type, with a crest length of 1760ft. The construction of the dam will require the placing of some 2½ million cubic yards of concrete. Water stored in the lake is to be utilised in two power stations, placed " in cascade," one at Fionnay and the other one at Riddes. A tunnel 15,600ft long, having a diameter of 10½ft, driven in a strong rock, without any lining, leads water from the dam to the Fionnay power house, which will be equipped with two (later with three) Francis turbine sets each of 42·5MW. A regulating reservoir will be connected to another tunnel leading to the Riddes power station. This tunnel is 48,000ft long and 10·6ft in diameter, and ends at two penstocks about 6000ft long, which bring water, under a head of 3280ft to the Riddes station. There are to be five Pelton turbines, of 45MW each at Riddes. The overall output of both power houses is estimated at 761 million kWh.

Applications of the Small Gas Turbine*

By F. R. BELL†

In this paper, which is abstracted below, the author examines the characteristics of small gas turbines ranging from 30 h.p. to 400 h.p. and discusses their suitability for numerous transport and industrial applications. Their dependence to some extent on future component development, particularly that of a heat exchanger, is stressed in regard to several layouts.

ONE of the difficulties in developing small gas turbines is that there are so many different types which can be used and different combinations of various individual components. Everybody has his own ideas of the most efficient arrangement and it is often very difficult to prove without actual tests whether any particular suggestion is of use or not.

Heat exchangers are, unfortunately, one of the most difficult problems which will have to be solved in small gas turbines or for that matter on any gas turbine and it is only by using good heat exchangers that fuel consumptions will be competitive with petrol engines and diesels. The difficulty is that owing to the very large surface area required to transfer heat, and to the fact that only a low pressure drop can be tolerated, the heat exchanger becomes very large and, if it is to be sufficiently light, to be made of a large quantity of very thin tubes or sheet metal. If the metal is thin enough to make the heat exchanger of a reasonably light weight, then thermal shock causes cracking and leakage. Attention to detail, however, has already brought about a big improvement and there seems no reason why the heat exchanger should not be made with quite adequate life.

Radial Flow Turbine.—Fig. 1 shows the radial flow turbine, which is mentioned here as so many small gas turbines are making use of this that it ought perhaps to be discussed in a little more detail. The radial turbine in principle is a centrifugal compressor with the gas flowing in the opposite direction—that is radially inwards. There are no very conclusive arguments either for or against the radial flow system and only experience can finally show whether it is in fact better than the axial flow turbine. Three points are worth considering, cost, cooling and efficiency. From the cost point of view, the radial flow turbine is easier to machine but has much more metal to remove and requires a much larger forging and, therefore, uses more expensive material. The axial flow turbine would seem, provided suitable special machines are made, to be able to be machined equally easily and systems for forging have already been developed. Of course, if the turbine rotors are cast there will not be much difference in the cost, but it is very doubtful if cast turbine rotors will ever be much use. On the question of cooling, whilst it may be that the radial flow turbine is easier to cool, its larger surface area, something like double the area of the axial turbine, requires much greater cooling and the rather awkward thermal stresses will probably require lower blade temperatures than in the axial turbine. A comparison of efficiency shows no real advantage in most cases for the radial turbine and the latest test figures for axial turbines show somewhat higher values than in radial turbines of equal size. Comparisons have been made which would appear to show that the radial turbine is suitable for higher pressure ratios than the axial turbine at a given efficiency, but these have been based on a misconception about the allowable blade speeds on the two types.

Axial Compressors.—It is unlikely that below, say, 1000 h.p., there will be much use made of axial compressors for industrial use although they will probably be finally used in all sizes for aircraft work. This rather depends, though, on the cost of blade machining. If blades could be machined sufficiently cheaply, the axial compressor might find a market in a small gas turbine, but it has a big disadvantage in that it is much more sensitive to dirt which deposits on the blades and reduces its efficiency. One large gas turbine, in fact, after a number of hours' running, doubled its specific fuel consumption owing to this dirt deposit. This all means that axial compressors for industrial use would require air filters and it is possible that centrifugal compressors could get away without these. A gas turbine air filter would be very big and expensive and would probably nullify any advantage the axial compressor might have. Of course, for aircraft, which spend most of their time up in clean air, the filter is unnecessary.

Fundamental Difficulties.—There are certain fundamental difficulties in developing the small gas turbine although these do not appear in general to be those expected, and again certain other difficulties which have been expected are not really fundamental and are only a matter of sufficient effort being put into research to overcome the troubles.

It has generally been stated that the accuracy required on the small turbine in order to maintain clearance will be much higher than on the large turbine and will create difficulties. This is not in general true ; in fact, in a number of cases the reverse is true. Three reasons can be given for this ; first, small components can be machined to more accurate limits than large components. This is because of the machining processes involved and the machines available. Secondly, clearances, such as turbine tip clearances, because their effects are proportional to their percentage of the blade height, and because the blade root tip ratio on small turbines of this design do not have to be as large as in large turbines the effect becomes less important. And, again, bearing clearances which affect the amount of tip clearance necessary, while they do not completely scale down, are small relative

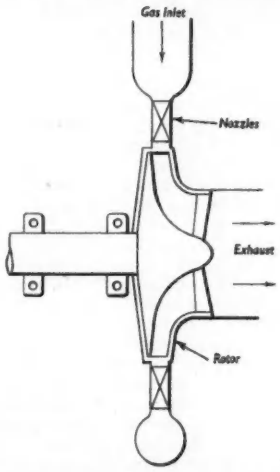


Fig. 1—Radial Flow Turbine

to the tip clearances. Thirdly, owing to the fact that the specific weight for small turbines can be slightly higher than in large turbines and because it is not usually possible on a small scale to make sheet metal and castings as thin as their strength will allow, the casings are more rigid than in large turbines and thus allow the holding of closer tolerances.

One of the most fundamental points about turbine design is that the Reynolds number should be large and that there is a small limiting Reynolds number at the low end below which turbine efficiency will fall rapidly. In practice, fortunately, Reynolds number effects are small and it would appear approximately in fact as if efficiency falls about 1 per cent each time the Reynolds number is halved. This is, however, a very rough approximation that does not apply in all cases and is open to some doubt. Below a critical Reynolds number the efficiency begins to fall very much more rapidly than this and at a rapidly increasing rate as the Reynolds number is still further reduced. It will, therefore, become impossible to make small gas turbines below some limiting size and there is no doubt that it would be quite out of the question to make an efficient small gas turbine down below a few horsepower. It would appear, however, that the lower limit for a reasonable efficiency is of the order of 30–50 h.p. and it is, therefore, not suggested that anything smaller than this will ever be satisfactory and it is not proposed in this talk to consider anything smaller than about these figures.

Aircraft Applications

A field which in future should become larger and in which the small gas turbine may have advantages is its use in the helicopter. Here the fact that helicopters are almost invariably used for very short journeys as their speed is too low for the longer flights is a big advantage for the turbine. For the short hop which the helicopter normally takes, the light weight of the gas turbine is a big advantage and its high fuel consumption is not so important as it is running for such a short time. It is almost certain that when suitable turbines are developed helicopters will be almost all turbine-powered. Already considerable development has gone on in this direction. One problem yet to be solved is the best method of drive. Several different drives may be used. First, the rapid acceptance of the jet engine led people to the idea that jets at the rotor tips operated by the jet engine feeding its exhaust gases up the rotor shaft and along the rotor blades would be a good form of helicopter drive as this appeared very light and simple. In fact, however, it has not turned out very satisfactory owing to the large size of the ducting through the rotor blades and to the large heat loss in the ducting. The next stop was to feed cold air bled from the compressor and to use combustion chambers at the rotor tips. This is a better method, but there is still considerable doubt about its efficiency as even cold air ducts are fairly large and require much thicker rotor blades than is desirable. Also the duct loss is quite high. Another disadvantage of both these methods is that for civilian use the noise from the jets is considerable and makes the aircraft rather unpleasant. The normal direct gear drive, although it introduces rather heavy gearing, is much more satisfactory from several points of view and in spite of the fact that for the past few years manufacturers have been trying to use these alternative methods, we may finally end up with a gear-driven rotor after all, particularly in the smaller sizes. Of course, it is quite possible that helicopters, particularly for Service application, will finally have ram jets at the rotor tips. This is obviously the simplest and cheapest method, but it is doubtful if the efficiency can be as high as with a normal gas turbine and, in any case, the ram jet is the noisiest thing in existence outside perhaps a rocket and may not be tolerated for civilian use.

Industrial Applications.—The most important advantage the gas turbine has over its competitors is its light weight. Where portable equipment is needed, and in most cases portable equipment is not used for long running times and, therefore, its fuel consumption is not very important, the gas turbine is certain to find a use. Unfortunately, certain portable equipment such as generators and compressors are at present very heavy. The light weight of the gas turbine is not so important as it could be if the equipment it drove was lighter. When lightweight compressors and light-weight generators are developed the scope of the gas turbine will be considerably widened. Of course, where lower air pressures are required, the gas turbine bleeding air as is done in the "Turbomeca" "Palouste," Fig. 2, has big possibilities. This type of engine in production should be considerably cheaper than a diesel engine plus its compressor and is, of course, very much lighter. Its fuel consumption is worse than the diesel, but this is compensated for in the case of portable equipment by the light weight.

If a large compressor is required to give constant pressure with varying flow, a free power turbine unit, because it can vary its speed over a wide range and still give constant torque, has advantages over the diesel engine. Quite a number of these types of applications are rather specialised and it does, therefore, appear that the gas turbine will be used industrially in a number of different arrangements. This raises the difficulty of making a suitable standardised range and it is necessary to consider carefully the design of the different types of engine in

* "The Industrial and Aeronautical Applications of the Small Gas Turbine," the Royal Aeronautical Society, Brough Branch, November 4, 1953.

† Chief designer (engines), the Blackburn and General Aircraft, Ltd.

order to produce a maximum amount of standardisation of parts. One might say, in fact, that the advantages of being able to tailor a gas turbine easily to suit the various applications is a disadvantage in that we are forced into making a number of different models of gas turbines.

Industrially the three forms of turbine likely to be of most use are, first, the free power turbine ; secondly, the single shaft engine, and thirdly, the air-bleed type of engine.

The existing range of " Turbomeca " engines covers broadly most of the requirements but does not cover everything yet in detail. One of the difficulties appears to be that industrial

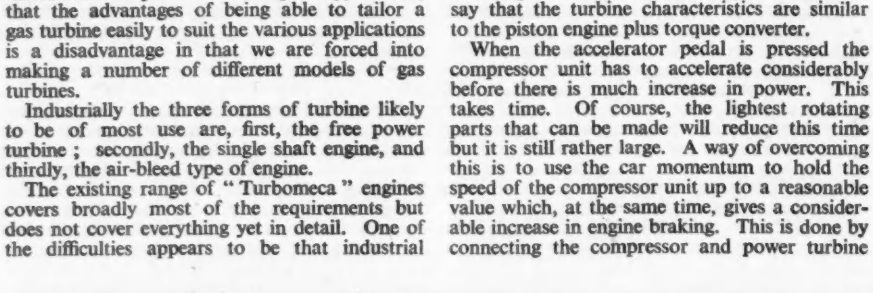


Fig. 2—" Patouste " on Transportable Stand

equipment requires to be driven at all speeds from something like 300 up to 12,000 r.p.m. This means that interchangeable gear ratios covering a wide range are required and these will have to be developed. Also a large range of powers is needed to cover all requirements and at present engines are available between 200 h.p. and 400 h.p. but industrially there are markets both lower and higher than this.

Road Transport Applications

Turbine Efficiencies.—It is probable that a car turbine will be similar to that used on the Rover turbine car. In this car a free power turbine is used and all auxiliaries are driven by the compressor unit, and it is fitted with a heat exchanger. Most important among the difficulties is the fuel consumption. There are two ways of improving this, first the components need better efficiencies as at present small compressors and small turbines are both less efficient than the large aircraft turbine and compressor. It is not expected that the small unit efficiency will ever be so high as that used in a large aircraft unit because of scale effects, but there is every reason to believe that the difference in efficiency will be very small. Improvement in efficiency is pretty certain to come, but is going to take considerable time and, in any case, the fuel consumption will never be good enough without heat exchangers, particularly at part loads.

Fig. 3 shows the power curves that such an engine should give and also the working line for steady running of the car geared so that it is just beyond the peak of the power curve for the power turbine, causing a drop of a few per cent in power but matching up better during acceleration. An engine of about this size with an air mass flow of about 2 lb per second will give about 100 h.p. and will have a specific consumption as shown in Fig. 4, compared with a specific consumption of an engine with the sort of component efficiencies we may get with development.

Gear Ratios.—One of the main advantages of the turbine is that its torque curves are such that it can perform adequately with practically no gear changing. It is, however, possible that a two-speed box is an advantage. One might say that the turbine characteristics are similar to the piston engine plus torque converter.

When the accelerator pedal is pressed the compressor unit has to accelerate considerably before there is much increase in power. This takes time. Of course, the lightest rotating parts that can be made will reduce this time but it is still rather large. A way of overcoming this is to use the car momentum to hold the speed of the compressor unit up to a reasonable value which, at the same time, gives a considerable increase in engine braking. This is done by connecting the compressor and power turbine shafts together with suitable clutches and controls so that in top gear at say about 30 m.p.h. the compressor unit will be running at about 35,000 r.p.m. In practice, we would adjust a slipping clutch to give braking effect something like equal to third gear over-run braking in a normal car. Obviously this system gives no improvement in acceleration at low speeds. This is easily overcome, however, by arranging the starter motor to start through a roller clutch and to be brought in to accelerate the engine at low speeds. This means that when the foot is pressed hard down on the accelerator at low speeds a contact is made that energises the starter. Fig. 5 shows the change gear and reverse arrangement, together with the regenerating braking system as we mistakenly call this system, fitted to an engine of about 100 b.h.p.

Exhaust Position and Silencing.—The car turbine exhaust contains very little more heat than the piston engine's exhaust plus radiator cooling air, but is not easily blown clear and has fumes so that it cannot be discharged under the car as a car cannot be made completely fume-proof. With petrol as a fuel the amount of fumes may be small enough not to worry about, but a big advantage of the turbine is its ability to burn low-grade fuels. The only cure seems to be to discharge upwards and towards the rear. This is a fundamental point to be considered early on as the layout of the car is affected by it. The turbine needs large exhaust ducts and these cannot easily be taken along under the car. We have, therefore, to put the engine at the rear with the exhaust upwards. Inlet noise is easily reduced by a simple absorption silencer consisting of splitters or partitions with sound-absorbing material fitted inside perforated metal. A similar scheme can be used for exhaust and is quite effective. Engine-casing noise is purely a matter of correct balance and when the balance is sufficiently good is quite negligible. A well-balanced engine will probably not transmit any noise through the mountings to the body, but if there is any trouble rubber mountings can be used.

Having considered the difficulties, it is perhaps fair to mention the advantages. First, the turbine car is very easy to drive as it requires no gear changing and consequently it is also very much smoother in its acceleration. It is quite free from vibration and noise and should have a longer life between overhauls and will be much less sensitive to the type of fuel it uses. The aircraft gas turbine in practice has shown these characteristics very well.

Buses and Lorries.—In the matter of buses or lorries, the whole question hinges on the importance of fuel consumption. Obviously if the fuel consumption of the turbine, as it undoubtedly will at some time in the future, be reduced to that of the diesel engine, then the gas turbine will be used for all buses and lorries. The reason this statement is made is that from all other points of view the gas turbine appears better. If, however, the consumption cannot be reduced to a figure equal to the diesel, or rather until such time as it is reduced to this figure, the position is not clear. The turbine has better torque characteristics, much simpler gearboxes, easier and smoother driving. It will put up much higher speeds on the road and allow—when the distances between refuelling are short, a higher pay-load. Maintenance costs will probably be lower. Although at present the turbine is expensive in large-scale production, it will probably cost less. The lack of vibration may improve the life of the rest of the vehicle.

Tanks and Tractors.—At present the Army, as far as is known, are not doing much about the question of gas turbines for tanks and Army vehicles. The trouble in any case is that one of the biggest difficulties in a tank is getting a sufficiently long cruising range. There is a possible future for the turbine in the ordinary tractor as used industrially and on farms. Because of its high power and extreme flexibility a tractor powered with a gas turbine could probably do considerably more work than a normal tractor, but would use considerably more fuel to do this.

Marine Applications

It would appear that in various different fields in the marine world the small gas turbine has a most important future. Unfortunately though, none of the marine uses seems to require any large numbers so that marine use is not of much help in setting up large-scale

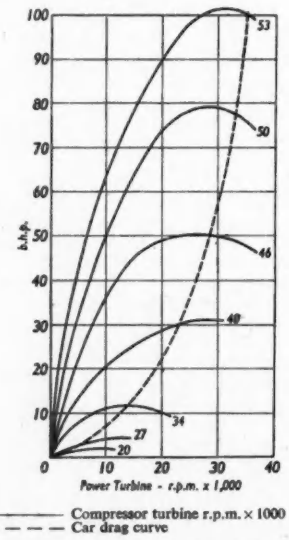


Fig. 3—Typical Power Curve for 100 b.h.p Turbine

production of turbines which is necessary to reduce their price. Already in the larger sizes the marine gas turbine is being used and it is fairly certain that at some future date, although this may be a good way in the future, all ships will be driven by gas turbines.

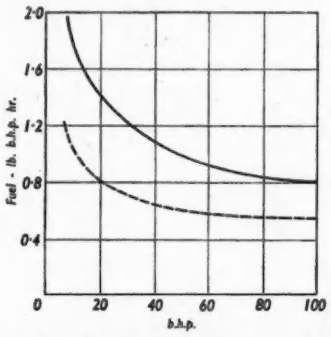
Small Craft.—For certain purposes the small gas turbine, such as the " Turbomeca " and Rover, are already quite suitable for use in small boats, but owing to their high fuel consumption, their particular scope is somewhat limited. It has been found, however, and was very clearly demonstrated on the Rover turbine-driven launch " Torquil," that the big

saving in weight caused by the introduction of the turbine gives a big increase of speed in a planing type boat for the same power. For short range use where a large amount of fuel is not required this is a very useful gain. For certain Naval purposes, where only short runs are required, the gas turbine would also appear to have a big future. Apart from the advantages of light weight the free turbine unit is very flexible and matches the propeller characteristics very well. This gives, as compared with diesel engines, a somewhat improved performance under widely varying conditions. Perhaps one of the biggest advantages of the gas turbine for private marine use is its smoothness and quietness. It is also possible that some advantages may accrue from the fact that the light weight turbine can be placed in a specially designed hull right aft and therefore make a better arrangement of living space. The present diesel engine is far too heavy to place aft.

Auxiliaries.—The other field in which the small gas turbine may be useful is for various auxiliary plant in large ships, such as power for winches and pumping plant in tankers. Because this plant is only required for a short time in port, it is uneconomical to carry about a heavy engine for this use and the rather high fuel consumption of the gas turbine is no disadvantage.

Future Developments

Mixed Cycles.—Quite a number of suggested, so-called mixed cycles have been worked out, the simplest, which may have useful applications, is merely to spray water into the gas after it leaves the combustion chamber and before it reaches the turbine. It takes much less power to pump water up to a given pressure than to pump air up to the same pressure, so that by having water to reduce the temperature of the gases to that suitable for the turbine instead of feeding excess air into the compressor we can produce a slightly more efficient and certainly a much more powerful engine. What would be done would be to burn fuel in the whole of the air which the compressor supplies—that is to use the whole of the air at the correct air : fuel ratio for complete combustion and then feed water in to reduce the temperature. This means that the mass flow through the turbine is considerably greater than through the compressor and, therefore, a much greater power is available, something like two or three times the power output being possible. The gain in fuel consumption, however, is only small because the heat required to supply the latent heat for converting the water into steam is quite large. The water would have to be pre-heated in a sort of heat exchanger in the exhaust which would recover some of the waste exhaust heat. The trouble with this system is that it uses vast quantities of water and will only be suitable where this water is readily available. This means that if it is to use sufficient water it can only be for stationary land use. There is a possibility, though, that salt water can be used, which would make this a very satisfactory method for marine uses. While certain problems would have to be solved in order to use salt water, these are not impossible. They are as follows : First, salt would deposit on the turbine blades and nozzles. It is felt that this would probably not matter very much as the unit could be made to run just at the melting point of salt such that only a thin film would deposit on the blades, which would be a protection and would keep them somewhat cooler. When the film thickened up it would melt off. This only applies to the salt, however, and the bigger difficulty would be the deposits of other materials contained in the sea-water. There may be other methods of inhibiting this deposit and also of inhibiting any corrosion which might occur. The other difficulty is that salt would certainly clog a heat exchanger; this means that with the salt water system no heat exchanger type of engine could be used, but nevertheless the big gains in power might make this system useful.



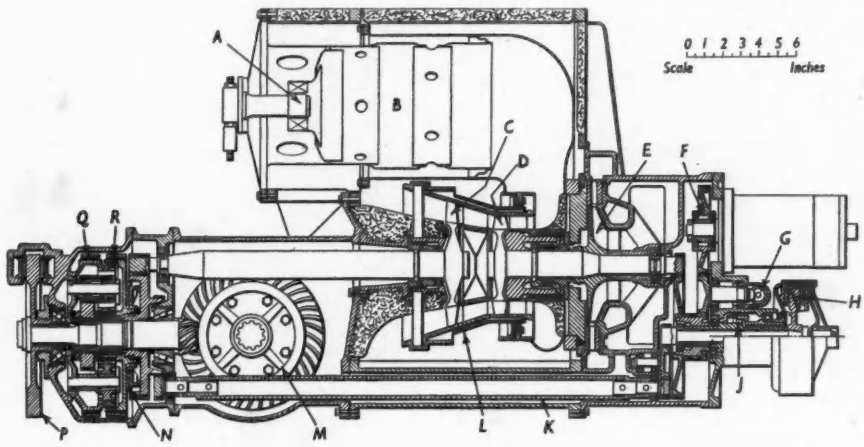
———— Best obtainable with present component efficiencies
– – – – Attainable with component efficiencies approximately equal to those of aircraft units

Fig. 4—Fuel Consumption Curves

Another way of overcoming the difficulties would be to have a form of continuous evaporator in the exhaust which would cause the salt to be left behind and to be cleaned out by some other method. This would give a very useful type of engine, but may be a rather difficult development problem. It is possible that salt could be centrifuged out of the steam before its temperature is raised to the melting point of the salt. The other form of mixed cycle which, although more complex, gives somewhat better results is to use the exhaust of the gas turbine to work a steam boiler which drives a steam turbine. It is very doubtful if the cost of this type of unit could be justified in small sizes.

Closed Cycles.—It has been thought that one of the advantages of the closed cycle system is its ability to use working fluids other than air because there is no loss of working fluid. This does not appear to be a real advantage as an investigation of all possible gases that may be used shows in general that they all have advantages and disadvantages in different directions and these nearly always neutralise each other so that air is finally just as good. Some of the typical advantages and disadvantages are as follows. First, inert gases such as neon can be used and these would cause no oxidation or corrosion troubles which would somewhat simplify the metallurgy of the turbine. These inert gases suffer from other disadvantages, in some cases their light weight, which involves large equipment or their lower value of specific heat, which also involves large equipment. Other types of gases that are heavy, such as carbon dioxide, would make a compact unit, owing to their high weight, but owing to their unfavourable value of the ratio of specific heats usually require higher pressure ratios in the compressor and turbine, which makes these very expensive. Certain monatomic gases have the opposite effect—that is, require only a very low pressure ratio, which makes a simple, cheap compressor and turbine, but these are usually rather light in weight and require big equipment. Again, certain complex gases, such as Freon, dissociate at gas turbine temperatures and contrary to the conditions in a piston engine, dissociation improves the efficiency and power output of the gas turbine. The effect is that the specific heat during expansion in the turbines is much higher than in compression and this is a useful gain. These gases, though, usually require higher pressure ratios and are not very suitable in various directions.

Atomic Units.—It is perhaps interesting to speculate on what might some day be produced in the way of the small atomic gas turbine. No definite information has, of course, been made public on sizes and weights for atomic reactors, but it would seem that a piece of plutonium 6in in diameter would produce far more than enough power to drive a car and would last for more than the lifetime of the car. If the heat transfer problems can be solved, and this will probably be solved by the use of a circulating fuel system, then one could make a car which would never require fuel during its life-time ; in fact, when the car was worn out its fuel could be transferred to the new car. The biggest problem, however, and one that does not appear possible of solution at present, is the shielding from radiation. In the near future it may be possible to make such a car as has been described, but it would not be possible to live anywhere near the car. Whether the question of radiation shielding will ever be solved is open to doubt. At present, as far as is known to the public at any rate, there is no solution.



A Burner
B Combustion chamber
C Power turbine
D Compressor turbine
E Compressor impeller
F Starter free wheel
G Tachometer drive
H Friction clutch
J Free wheel
K Regenerative braking shaft
L Shroud ring cooling air
M Differential
N High-ratio clutch
P Disc brake
Q Reverse clutch
R Low-speed clutch

Fig. 5—Sectional Elevation of 100 b.h.p Turbine Unit with Transmission

Short Notice

Modern Pumps. Edited by E. Molloy. London : George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. Price 21s.—This book is described as "a comprehensive survey of modern pumping equipment and practice." In the first five chapters the principles of pumping are discussed, some elementary principles and general terms being given in the first chapter, followed in the next chapters by explanations of the basic ideas of reciprocating, centrifugal and rotary pumps, and of the installation and the maintenance and repair of pumping plant. The application of the different sorts of pumps to particular duties forms the subject matter of the second half of the book, and there are chapters on pumps for boiler feeding, mining, the oil industry, and for wells and boreholes. A chapter entitled "Pumps for Special Applications" describes pumps suitable for working with sewage and waterborne solids, for drainage, irrigation and contracting work, and pumps for special liquids. Some of the more specialised kinds of pumps—for instance, vacuum pumps and fuel injection pumps—are not dealt with. There is an appendix containing reference and conversion tables.

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SUPPLEMENT—"R.M.60" Marine Gas Turbine

NUCLEAR ENERGY DEVELOPMENTS

The recent official announcement of the completion of the second series of this year's Anglo-Australian military tests at Woomera, coupled with the good news of the schemes being pushed forward on both sides of the Atlantic for the building of nuclear reactors for peaceful purposes, are as welcome as they are important. They mark real steps forward which, taken with earlier statements, are likely to lead to the definite introduction of new forms of weapon in each of the British and American Defence Services, and to an approach to the day when nuclear energy will be used on no inconsiderable scale for civil purposes. The official announcement about the Woomera tests stated plainly that the objective was to obtain certain important scientific information required by the Governments in connection with their programmes of weapons development, and that their successful completion fulfils the programmes as originally planned. Australia is fortunate in having at Woomera so admirably effective a testing range for atomic and other purposes, as well as in the possession of such extensive uranium deposits for providing the necessary raw material. The initial sentimental opposition to the use of atomic weapons in any shape, recalling the reluctance felt long ago at the introduction of the cross-bow and, later, of the musket and the rifle, has now largely evaporated among the better informed public, and certainly in the minds of those who are in charge of our affairs.

The use in warfare of atomic energy in any form began in 1945 and led to very heavy casualties at Hiroshima and Nagasaki. They were, however, by no means so large as those caused a few months earlier in an air attack on Tokyo by ordinary incendiary bombs. Fortunately, in their newest forms, one of the purposes of nuclear weapons is to improve the power of field artillery, and in this way to afford a welcome increase in the defensive power of relatively small armies against the massed hordes which some large countries might prove capable of putting into the field at short notice for sudden aggression. Such aggressive action is likely in future, one may hope, to recoil with drastic severity on the attacker. The knowledge that this is so may well be one of the greatest, if not the greatest, factor that now exists in favour of peace in our time. These considerations make some of the forms of secrecy hitherto surrounding the scientific principles involved increasingly absurd. Happily, they seem to be beginning to grow less onerous. There is, for example, less fear than there once was of allotting a certain amount of fissile material for reactors capable of producing electric power for civil purposes. Indeed, there have lately been official announcements of the building of more ambitious plants for this purpose than anything hitherto proposed. The United States Atomic Energy Commission let it be known in October that a Government contract had been placed with the Westinghouse Company for an industrial power breeder reactor to provide 60,000kW of electric power. It is expected to be sited at some spot where convenient access is available to existing U.235 separation plants, perhaps at Oak Ridge (Tennessee), at Paducah (Kentucky) or Portsmouth (Ohio). The cost of this reactor is expected to be in the neighbourhood of 30,000,000 to 40,000,000 dollars, and the time for construction three or four years. It is stated that on completion, it will be operated by the Government itself. That decision may seem surprising in view of the fact that no less than five pairs of industrial teams have been at work in U.S.A. for at least a year on the study of possible adventures of this kind. But the conclusions those teams have reached, so far as they are known, hardly seem to be of a kind to encourage a Government to hand the task over to them or to encourage firms to embark on the adventure unsupported. There seem to have been two principal uncertainties, one a doubt as to the likely amount of the capital cost involved, and the number of years it would take for its amortisation, and the other a doubt about the earnings that could be expected by the sale to the Government of the by-product plutonium, particularly as the demand from that sole purchaser might sooner or later dry up altogether.

Information, though not on quite so generous a scale, has also been liberated by our own Government. Early in the year the Minister of Supply mentioned that work was in hand at Harwell and Risley on the design and development of a full-scale breeder reactor capable of producing substantial amounts of electricity. This, however, was not quite the same thing, as it related in the main to the production not of electric power, but of plutonium. But the Minister had more relevant news to impart in recent weeks when he forecast that some 50,000kW might in all be obtainable from the new power-producing reactor being constructed in Cumberland and the breeder-reactor previously mentioned. He said that, although it was too early to predict when a significant contribution to our national electricity supply would arise from nuclear energy, nevertheless, he saw no reason why it should not some day provide a useful addition to our power resources. He did not then indicate whether such power plants would be designed by Government establishments or by industry. Now, however, the situation has been clarified. On page 633 we print, slightly abridged, the White Paper on "The Future Organisation of the United Kingdom Atomic Energy Project," which summarises the proposals of the Government to set up a non-departmental organisation, to be called the Atomic Energy Corporation, to take over nuclear research and to develop industrial uses of atomic energy. That is unquestionably a step in the right direction. But it is only a step. For though the White Paper remarks that "as the industrial uses of atomic energy become relatively more prominent the case for a form of control of the project which is more akin to the structure of a big industrial organisation becomes increasingly strong," it can hardly be said that the organisation of the Corporation and the method of controlling its finances have much similarity to those of industry. Sooner or later, if the development of civilian uses of atomic energy is to be really actively pursued, private industrial firms will need to be allowed and encouraged to pursue research and development upon their own account. However, as experience in the United States seems recently to have shown, the returns to be expected by industry from investment in research and development in this field are so speculative and would take so long to realise that Governmental financial support remains essential. In these circumstances, and because the Government wants to retain secrecy, the setting up of the Corporation, as recommended by the Waverley Committee, seems the only reasonable compromise. But is so much secrecy really justified ?

SURGE TANKS

In striving after greater efficiency and higher economy in use it seems inevitable that machinery—and, indeed structures, too—should become more complicated. There was a day when electric power could be generated and distributed by a hand-fired boiler, a steam engine, a boiler feed pump, a dynamo and a knife-switch or two. To-day there are chain-

grate stokers or pulverised fuel burners, water-walls, superheaters, desuperheaters, steam reheaters, bled steam feed heaters, drain coolers, condensers, circulating pumps, extraction pumps, de-aerators and evaporators; and transformers and switchgear enough to occupy an amount of room comparable with that taken up by the turbine. There was a day when a fighter aircraft flew at 100 m.p.h. and contained an engine, a compass and an altimeter, and very little else. To-day it flies at a Mach number approaching unity, is packed with hydraulic and electronic devices and moves so fast that the pilot is unlikely to find, much less shoot down, his target without the help of radar. Even the basic single-shaft simplicity of the gas turbine is suffering a sea-change in the hands of makers for industry and marine propulsion. Shafts multiply and so do coolers and intercoolers, heat interchangers and stage compressors and turbines. Much the same thing applies, as the members of the Institution of Mechanical Engineers learned last Friday, to hydraulic power schemes. No doubt in the past the operators of overshot water-mills noted a slight surge of the water level in the upstream mill pool when starting up or shutting down. But they had no need to build surge tanks or enter upon mathematical investigations about their design, or complex step-by-step calculations to determine their dimensions ! Indeed, it is probable that even within quite recent years open surge tanks at the junctions of pressure tunnels with pipelines have been designed and built under the guidance of rules of thumb based upon past experience rather than upon the basis of involved calculation. The special interest now being taken in the theory and in the calculation of surge tank dimensions has arisen from a greater appreciation of the surges of electrical load that can fall upon hydro-electric stations linked to a grid network and from the recent trend towards the construction of underground power stations, some of which may require excavated surge tanks downstream of the machinery.

In many fields it has proved possible eventually to reduce abstruse mathematical theories to simple rules of thumb or nomograms which ordinary design staffs, unable fully to comprehend the original theory, can use with confidence. But whether the design of surge tanks will ever be reduced to so simple a basis—perhaps we should write come back to it—cannot be foretold. It does not seem very likely. For rules of thumb usually provide only approximate answers. But when a rock excavation for a downstream surge tank may be comparable with or even greater than that for the power station itself, an approximation can prove expensive ! More exact calculation may prove less costly, even though it involves, as surge tank calculations do, laborious step-by-step analyses repeated, perhaps, for a number of differing conditions, each of which may be critical ; and repeated again whenever modifications are studied. But it is a weakness of mathematical methods that, to quote Mr. Linton's contribution to the discussion of Dr. Jaeger's paper before the Mechanicals (abstracted elsewhere in this issue), " many of the assumptions from which mathematicians cheerfully construct their theories do not always hold in practice." He pleaded, therefore, for a more extensive use of models in surge tank investigations, partly on the ground that some factors might be introduced into the model that could not be introduced into the mathematics. It is a plea that will appeal to engineers designing hydro-electric power schemes, but it is one which, as Dr. Jaeger's reply to the discussion brought out, it is not wholly easy to meet. Nor obviously should too much trust be placed in models. For if in mathematical theorising very much depends on the skill of the mathematician in choosing reasonable simplifying assumptions, so, too, in constructing a model simplifications need to be made. Advances will best be made, in this field as they have been in many others, when mathematical and model investigations go hand in hand.

Very largely, so far, to judge by Dr. Jaeger's paper and its discussion, the problem has been considered to be one of designing surge tanks to suit certain precalculated loading conditions. But, in fact, other factors may influence the design. Mr. Zienkiewicz remarked that " it may be possible to introduce instability by too sensitive governing. There must be many practical cases of the borderline where the quite considerable cost of the provision of a surge tank can be countered by the installation of less sensitive governing and larger inertia of the machines." Nor should the electrical side be neglected. Provision must obviously be made for the sudden removal of load that may occur when circuit-breakers come out. But, even when a station is linked into a grid network it may be possible electrically (or mechanically ?) to limit the rate at which load can be picked up or at least to prevent a dangerous off-load/on-load sequence. Mr. Headland, for example, referred to the effect of the " advent of automatic re-closing and possibly single pulse switching on high-voltage transmission systems where the circuit breakers could re-close automatically a few cycles after opening," and felt that " a co-ordinated review between the hydraulic design engineer and the system operating engineer would be valuable."

Literature

The Welding of Austenitic Corrosion and Heat-Resisting Steels. Compiled by THE BRITISH WELDING RESEARCH ASSOCIATION. London : The British Welding Research Association, 29, Park Crescent, W.1. Price 27s. 6d.

EVER since stainless steel was first used in industry some forty years ago, a great deal of attention has been given to methods of joining it to form the multitude of different assemblies for which it is used. The unique corrosion and heat-resisting properties of the stainless steels make them invaluable for carrying out processes and withstanding arduous conditions of operation that were not possible with older materials. In joining the various components to form the finished assembly it is obvious that welding should receive more attention than any other assembly processes, since crevice-free joints can be produced, in which the properties of the weld can be very similar to those of the parent material. Very many problems have had to be overcome, and, in developing welding processes, materials and techniques which give the desired results, the ingenuity of metallurgists, steel makers, and welding engineers has been taxed to the full. This book gives for the first time a clear, comprehensive and authoritative statement on the present position with regard to the welding of these steels.

It is the result of years of intensive work by a committee of specialists, brought together by the British Welding Research Association, including representatives of both steel manufacturers and users. The scope is limited to stainless steels of the 18/8 class, which has enabled this subject to be treated in a reasonably detailed manner.

The book is essentially intended for the engineer—that is to say, those men closely connected with and responsible in industry for fabricating stainless steel components, such as food and chemical containers, gas turbine engines and the like. For instance, eight of the nineteen chapters are devoted in turn to each of the main welding processes, and emphasis is most correctly placed upon Argonarc welding.

Inevitably, a book on this subject must deal with fundamental metallurgical matters, and two chapters, one on metallurgical considerations and the other on heat-treatment after welding, adequately cover this aspect. These two chapters deserve special praise, because they cover relatively complicated metallurgical matters which must be appreciated by the engineer, but do so with such clarity of style and simplicity of expression that their meaning can be readily appreciated by those who possess only a relatively scant knowledge of the subject. The problem of carbide precipitation is described, analysed and put in its correct perspective, together with the necessary information as regards remedial action.

Cutting methods for stainless steel receive special attention. Attention is focused on oxidation and fluxing methods of cutting, as distinct from mechanical methods, such as guillotining, sawing and drilling. It is claimed that the latter are slow and costly owing to the tough work-hardening nature of 18/8 steels. Nothing is said, however, of the recent and popular process which involves the use of an extremely high-speed bandsaw.

Data on proprietary makes of 18/8 steel, and of chromium-nickel heat-resisting steels, are given in an appendix, together with relevant standard specifications. The selected bibliography and index are well prepared.

The book will be found very useful to engineering foremen and works managers who are connected with the production of stainless steel assemblies. The general quality of the text and illustrations is of a high standard. Technically, it is a landmark in the history of the British Welding Research Association, and deserves a warm and wide reception.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

A GREAT LOCOMOTIVE CLASS

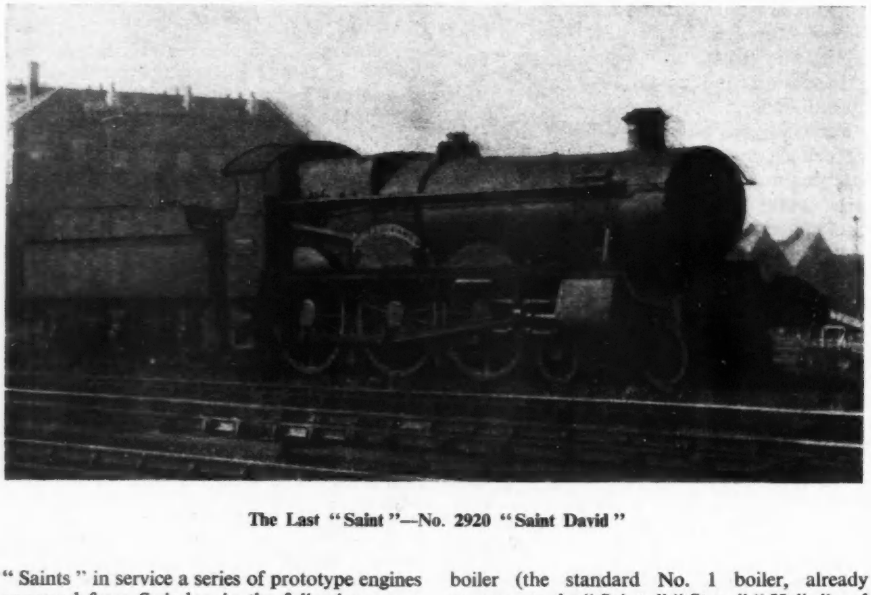
SIR,—The last of the former G.W.R. " Saint " class engines, No. 2920, " Saint David," was withdrawn from service on October 5th and is now at Swindon works.

Well within their own lifetime the " Saints " attained a dominant place in British locomotive history, and it may be argued that their influence on design during the past fifty years has, directly and indirectly, probably been greater than that of any other engines. Therefore the principle having apparently gained general acceptance that the most famous of our locomotives should be preserved, there is surely reason to expect that this last " Saint " should be amongst them.

It is probably unnecessary to trace the influence

of the "Saints," as this has often been done more thoroughly and more expertly than I can attempt, but the main outlines may perhaps be sketched again in this special cause.

The early engines of what subsequently became the "Saint" class were, as is well known, the first engines to be built in complete accord with Churchward's ideas. They represented a fundamental change from what had gone before, and from them was evolved virtually the whole of subsequent locomotive practice on the G.W.R. After successful initial experience with the



The Last "Saint"—No. 2920 "Saint David"

"Saints" in service a series of prototype engines appeared from Swindon in the following years, 1903–11, all embodying the essential features of the parent design, but each adapted for a different range of duties. Most of these types (e.g. the heavy freight 2–8–0 No. 97, now No. 2800, and the mixed-traffic 2–6–2T No. 99, later No. 3100 and No. 5100) were, like the "Saints," later built in large numbers. As they gradually replaced older designs in service the great simplicity of the policy underlying them became evident: the Great Western Railway locomotive stock was to comprise no more than about a dozen essential types all closely related in design and components, simple in design, and which—as events proved—were very reliable and set a standard of economy in operation so far removed from the generally accepted standards of the time that it seems to have been for many years to have been scarcely comprehended elsewhere. The slowness with which the relevant features of design were actually applied on other railways is surely one of the most remarkable features of modern British locomotive history.

One early derivative of the "Saints" has, by its own brilliance, tended to dim the lustre of the parent design. For various reasons Churchward did not favour his basic two-cylinder, Stephenson geared design for the principal long-distance express passenger duties, and produced, in 1906, a four-cylinder, Walschaerts-geared engine of comparable power to the "Saint." This was the first of the wonderful "Stars" from which, in turn, the "Castles" and "Kings" were evolved. Thus, early in their great careers the "Saints" became second-line express engines and had perhaps a less spectacular and somewhat tougher time than the "Stars." Happily, No. 4003, "Lode Star" has been preserved, and we may also for a time see the few late survivors about their duties.

The great pattern of development initiated by Churchward with the "Saints" was continued by his successors right up to the end of Swindon's independence, and the basic design gained rather than lost in importance. For example, when, in the changed traffic conditions after the first world war, the need arose for a wide-purpose mixed-traffic engine of similar power to the express passenger and heavy freight types one of the "Saints," No. 2925, "Saint Martin," was rebuilt in 1924 with 6ft coupled wheels in place of the original 6ft 8½in. Now, as No. 4900, it stands at the head of the 329-strong "Hall" class. Then, in 1936, eighty of Churchward's 5ft 8in 2–6–0s of the famous "4300" class were renewed with a leading bogie and an enlarged boiler (the standard No. 1 boiler, already common to the "Saints," "Stars," "Halls," and "2800" class heavy freighters) to form the "Grange" class—a 5ft 8in wheel "Saint," which had in fact been part of the original Churchward plan of 1903–11, though not proceeded with at that time. Finally, the last major Swindon design, the Hawksworth "County" of 1945, reverted to the basic two-cylinder pattern for certain express duties, and may in a sense be regarded as a renewal of the "Saint."

Beyond the Great Western the greatest spread of the Churchward idea followed the appointment of Sir William Stanier at Crewe. The broad pattern of his new types of engine for the L.M.S. and the essential principles of their design had a very strong Swindon flavour. In particular, the ubiquitous "Black 5" 4–6–0s are very closely related to the "Saints."

Perhaps the clearest echoing of the Churchward idea is to be found in the standard classes of engine now being produced for British Railways, and again the similarity lies both in the broad pattern of types, and in the general principles of design. Much of the detailed design comes also, directly or via Stanier, from Churchward. We may indeed wonder what engines would be building for British Railways to-day had—other things being the same—Churchward not produced the "Saints" and their derivatives, but had instead merely enlarged the designs (and they were very good ones, by ordinary standards) of his predecessors. It is a fascinating speculation, and serves to place the "Saints" in their rightful position in British locomotive history.

It would be a fitting recognition of this position, and of the genius of Churchward, for "Saint David" to be preserved alongside "Lode Star." It is a fortunate chance that there is the opportunity, not only of preserving an example of each design, but also of the two class names—"Saint" and "Star"—which will, in any event, be coupled in immortality.

R. J. DORAN

Heston, Middlesex, October 28th.

THEORY OF COMPLEX STRESS CREEP

SIR,—Some months ago, in the *Transactions of the Royal Institute of Technology*, Stockholm, Sweden—No. 66, Professor F. K. G. Odqvist put forward a theory of complex stress creep based upon the equation for tensile creep:

$$e = e^{(o)} + t\dot{e} \text{ *}$$

where $\dot{e}$ is the asymptotic (minimum) creep rate, $e^{(o)}$ the intercept of the extended linear portion of the creep curve upon the axis of creep strain, e being the total creep strain and t time.

Using the usual notation:—

σ_{ij} = stress tensor
s_{ij} = stress deviator
e_{ij} = strain tensor
$\sigma_e = \left(\frac{3}{2}s_{ij}^2\right)^{\frac{1}{2}}$ = effective stress
$e_e = \left(\frac{2}{3}e_{ij}^2\right)^{\frac{1}{2}}$ = effective strain

neglecting elastic deformation, and assuming negligible volume change during creep ($e_{KK}=o$), he stated his theory in the equation:—

$$\frac{de_{ij}}{dt} = f(\sigma_e)s_{ij} + g(\sigma_e)\frac{ds_{ij}}{dt}$$

where $f(\sigma_e)$ and $g(\sigma_e)$ are functions to be determined by experiment.

Obviously for $t=o$, $e_{ij}^{(o)} = g(\sigma_e)s_{ij}$, giving the value of the intercept on the axis of creep strain.

Equally, the asymptotic constant creep rate has the value $\dot{e}_{ij} = f(\sigma_e)s_{ij}$.

In an effort to evaluate the functions $f(\sigma_e)$ and $g(\sigma_e)$ Professor Odqvist made considerable use of combined stress data obtained by A. E. Johnson on 0·17 per cent C steel,† RR59 aluminium alloy, magnesium alloy, and Nimonic 75 at various appropriate temperatures.

He computed $e_e^{(o)}$ and $\dot{e}_e$ from lines of best mean slope round about 200 hours, in the tests mentioned above, and by double logarithmic plotting of σ_e against, respectively, $e_e^{(o)}$ and $\dot{e}_e$ he reached the conclusion that in most instances relations of the type

$$e_e^{(o)} = \kappa_o \sigma_e^{\overline{n_o - 1}}$$

and

$$\dot{e}_e = \kappa \sigma_e^{\overline{n-1}}$$

existed where κ_o, n_o, κ and n were constant.

The writers wish to make certain comments concerning the above equations and the mode of their derivation. These comments are as follows:—

Firstly, the minimum or asymptotic creep rate for each member of a family of creep curves for a given material at a given temperature commences at periods which increase very considerably as the stress is reduced. (We consider the general case, and not that of a material at a temperature sufficiently high to make all except steady-state creep negligible in value.) Thus, in the case of the RR59 alloy mentioned in Odqvist's paper at 150 deg. Cent. and 4 tons per square inch torsion, the creep rate is still decreasing after 4000 hours; the ratio of the rate at this period to that at 200 hours is actually as 1 to 12.

Accordingly, average rates round about 200 hours such as Odqvist has measured, and used to compute his $\dot{e}_e$, can have, in general, little relation to the minimum rates he really requires to illustrate his theory. Equally, the intercepts on the creep strain axis will be considerably smaller round about 200 hours than would those corresponding to the real minimum rate constant slopes. Thus, the relations Odqvist

* In the course of the paper Odqvist incorrectly states that combined stress theories have only taken account of the linear portion of the creep curve. Actually, the relations obtained by Johnson refer mainly to primary creep.

† The data on 0·17 per cent C steel quoted by Odqvist was on highly anisotropic bar; further work was later done on isotropic castings of 0·17 per cent C steel.

derives on the basis of the 200 hour rates, viz. :—

$$e_c^{(o)} = K_o \sigma_c^{\overline{n_o - 1}} \text{ and } \dot{e}_c = K \sigma_c^{\overline{n-1}} \ddagger$$

are incorrect representations of the relations of the functions concerned with σ_e.

It is the writers' opinion that no single valued functions of the type concerned could be found to represent the general creep field as a whole, but this is a matter for future investigation. However, the expression put forward by Johnson, viz. :—

$$\dot{e}_1 = F(J_2) s_{ij} f(t)$$

($\dot{e}_1$, &c., are principal strain rates)

where J_2 is the second stress invariant and F and f are functions, represents well all the materials concerned up to 200 hours, i.e. represents geometrically similar curves of primary creep. At higher stresses allowance had to be made for anisotropy arising as a result of deformation, by modifying the terms of the s_{ij}, viz., e.g., $[(\sigma_1-\sigma_2)-(\sigma_2-\sigma_1)]/3$ by inserting differing arithmetical coefficients before the individual terms $(\sigma_1-\sigma_2)$, $(\sigma_2-\sigma_3)$ and $(\sigma_3-\sigma_1)$.

This gives rise to the second shortcoming of the Odqvist theory in the opinion of the writers, which is that the relation Odqvist proposes makes no provision for representing the anisotropy which arose in all materials concerned as a result of deformation ; indeed, Odqvist appears to doubt the existence of such anisotropy, attributing its apparent appearance to incorrect analytical approach.

Now, in the writers' view, this is inadmissible. In the tests concerned, whatever the analytical interpretation of the results, the curves representing the creep in axial and shear directions, and the rates measured from them, are basic data. The relative magnitudes of either the rates or strains concerned and of the principal strains computed from them, are an indication of the degree of isotropy maintained in the tests.

In the experiments undertaken, marked indications were given at higher stresses that the creep rate and strain in one direction of principal stress tended to zero, and the other two to numerical equality. Whatever the details of the analytical approach, it is difficult to see that this can be interpreted in any other way than that progressive anisotropy due to deformation occurs.

The rates for corresponding stress systems, but at lower stresses, corresponded to isotropic deformation.

In Odqvist's theoretical equations no provision is made to represent this manifestly present anisotropy.

On the above-mentioned grounds, the writers are led to suggest that the Odqvist theory cannot be considered as justified by the experimental data provided by Johnson's experiments.

A. E. JOHNSON
N. E. FROST

Mechanical Engineering Research Laboratory,
East Kilbride,
October 28th.

‡ Actually in his paper, Odqvist includes initial plastic strain in his $e^{(o)}$. In Johnson's papers only creep strain values are given, initial plastic strain being subtracted.

United Kingdom Atomic Energy Project

A WHITE PAPER setting out the Government's plans for the future organisation of the United Kingdom atomic energy project was published on Tuesday evening (Cmd. 8986). The White Paper says that as the industrial uses of atomic energy become relatively more prominent, the case for a form of control of the project which is more akin to the structure of a big industrial organisation than to that of a Government department becomes increasingly strong ; and it will, in the Government's view, become stronger with the increase in the need for closer contact and co-operation with industry, including the nationalised industries, and the widening application of atomic techniques. It is considerations such as these which have led the Government to conclude that the most rapid and economical development in this field will be secured by transferring responsibility from the Ministry of Supply to a non-departmental organisation with the necessary executive power, within the framework of an approved policy and under a financial ceiling, to settle day-to-day problems. The Government believes that the necessary flexibility and speed of decision can best be obtained from the board of an organisation run on industrial lines, and with no responsibility outside the field of atomic energy. The Government recognised, however, that the transfer of responsibility from the Ministry of Supply to a non-departmental organisation would present difficulties which would require careful study and which ought to be thoroughly explored before a final decision could be reached. It was also clear that, because of the need for close control of policy by the Government, and the dependence of the organisation on public funds, the form of the non-departmental organisation would be bound to differ from that of any now in existence. A committee under Lord Waverley's chairmanship was therefore appointed. That committee has considered the matter in detail, and has produced a comprehensive report which deals with many matters which, for reasons of security, cannot be disclosed, but a summary of the committee's main recommendations is included in the White Paper. All the recommendations have been accepted by the Government. The Minister responsible to Parliament for the future Corporation will be the Lord President of the Council. In addition it has been decided that the Ministry of Supply shall be responsible to the Services for the provision of complete atomic weapons. It will place contracts with the Corporation for the production of the nuclear components of such weapons and for research in relation to specific Service requirements ; and that the salaries offered by the Corporation should not be seriously out of scale with those paid by other public corporations.

The necessary administrative preparations for giving effect to the Committee's recommendations are now being made. An Order in Council under the Ministers of the Crown (Transfer of Functions) Act, 1946, will shortly be laid before Parliament, and this Order will transfer responsibility for atomic energy from the Minister of Supply to the Lord President of the Council as from January 1, 1954. Later, a Bill will be introduced to provide for the setting up of the Corporation. Finally, the White Paper stresses two points to which the Prime Minister drew attention in his statement announcing the setting up of Lord Waverley's committee. First, overall policy will remain firmly in the hands of the Government. While the Corporation will be given freedom in the day-to-day management of its affairs, including its finances, its operations must be governed by Government directives which will lay down its objectives and direct its policy. Secondly, the rights and interests of the existing staff will be fully respected and consultation with staff representatives will take place at the appropriate time.

Among the main recommendations of Lord Waverley's committee, which are set out in the White Paper are the following : "We recommend that an Atomic Energy Corporation should be established. This should be a statutory Corporation with an executive Board. There should be transferred to this Corporation from the Ministry of Supply the responsibility for the establishments at present controlled by the Atomic Energy Research Establishment ; by the Production Division ; and by the Atomic Weapons Research Establishment. The Ministry of Supply should continue to be responsible for the conventional components of atomic weapons. Well in advance of the vesting date, action should be taken to provide, in a form suitable for transfer to the Corporation, the majority of the common services provided at present by the headquarters divisions of the Ministry of Supply jointly for the Atomic Energy and other Establishments of that Ministry. The question whether or not to use the Ministry of Works as an agent for building services should be left for decision until the Corporation is established."

"There should be designated a Minister responsible to Parliament for moneys provided for the Corporation and for the policy directions given to the Corporation. The main task of this Minister will be to ensure the well-being and efficiency of the Corporation as a whole and the maintenance of a balance between the use of atomic energy for defence, for power and to an increasing extent in the biological applications, in conformity with policy laid down from time to time by Ministers collectively. This Minister should be one of the existing Ministers of high Cabinet rank who has no departmental responsibilities which encroach upon the field of atomic energy. The most suitable Minister seems to be the Lord President of the Council. There should be a Ministerial Committee representative of all the Ministers whose departments are concerned with the various aspects of atomic energy. The designated Minister should be the chairman of this committee. The designated Minister would require a small group of officials to assist him. These officials should constitute a small department responsible solely to him and should not owe allegiance to any of the Departments having a particular interest in the applications of atomic energy. An official committee representative of all the departments concerned with atomic energy will be required as at present. The Corporation should at the outset be given a directive requiring it to consult the official committee on all matters of external policy. The channel of communications for agreed decisions on such matters of policy should be through the Foreign Office or the Commonwealth Relations Office as the case may be. The Ministry of Defence should remain generally responsible, after the Corporation is set up, for the allocation of resources available for defence purposes between atomic weapons and conventional arms and for the distribution of effort between the research, development and production of atomic weapons."

About finance, the Waverley Committee says that the Corporation's expenditure will be very heavy and, at least for many years to come, its receipts will be relatively small. It says also that the Corporation should be allowed rather more flexibility and discretion in respect of capital expenditure than is usual with Government departments.

Other recommendations are that the chairman of the board of the Corporation should discharge the functions of a general manager. The board should include four whole-time functional directors : one for engineering and production, one for weapons, one for research and one for administration and finance. In addition, the appointment of two part-time members without a separate technical function is recommended. Special arrangements will be required in respect of salaries and conditions of service to enable the Corporation to compete with industry for men for all its top level posts ; below the top, however, all reasonable steps must be taken to avoid standards widely divergent from those in the Civil Service.

On transfer problems, the committee's main observation is that special consideration should be given to safeguarding, so far as possible, the interests of existing civil servants working in the atomic energy undertakings when responsibility for these is transferred to the Corporation.

Following the publication of the White Paper, it was announced from 10, Downing Street that, subject to Parliamentary approval of the legislation for the establishment of an Atomic Energy Corporation, it was proposed that Sir Edwin Plowden should be its first chairman. Meanwhile, Sir Edwin has accepted appointment to the staff of the Lord President of the Council. He will assist the Lord President with work concerned with the establishment of the new organisation for atomic energy.

Trends in Surge Tank Design

INSTITUTION OF MECHANICAL ENGINEERS

AT a meeting of the Institution of Mechanical Engineers last Friday, November 6th, a paper on "Present Trends in Surge Tank Design" was presented by Dr. C. Jaeger. An abstract appears on page 639. The following discussion took place.

DISCUSSION

Mr. Henry Headland, said that in these days of rigid economy of expenditure, the authorities for whom consulting engineers were called upon to design and construct hydraulic schemes concerned themselves more with detailed design, and surge tank dimensions were frequently challenged. The paper was valuable in emphasising the risks which might be run by being led into temptation with meagre designs and operating restrictions which might be forgotten or become inapplicable with changing system conditions. In the section of the paper which described the simple restricted orifice and differential tanks, he thought that the author might have indicated the conditions under which these various types were used and why Continental practice seemed to prefer the restricted orifice type, while their American contemporaries, until recently, had shown a distinct preference for the differential type. He was a little surprised that the author had made no reference to the behaviour of surge chambers during starting and stopping operations on pump storage schemes, where the turbine was called upon to assist in dealing with surges following an electricity supply failure, or where the recently developed combined turbine and pump could be used. The author rightly emphasised the surge tank design loading conditions. This, he believed, was probably the most unsatisfactory aspect of the whole problem and was a field in which a co-ordinated review between the hydraulic design engineer and system operating engineer would be valuable. He felt that the author might have made a short reference to the work done in Italy, and more recently in Germany, on the effects of repeated loading and unloading of the turbine. Two points had occurred to him in considering this load-on condition, and he mentioned them merely to illustrate the need for an appreciation of the wider aspects of design. They related to faulty synchronising, particularly in a single-machine station, simulating the effect of sudden short-circuit loading, and to the advent of automatic reclosing and possibly single-pulse switching on high-voltage transmission systems where the circuit breakers could reclose automatically a few cycles after opening. The author had mentioned model tests in a number of places, without stressing their limitations with regard to surge phenomena, or mentioning the application of differential analysers or computers, or the recent work of the Massachusetts Institute of Technology dealing with electrical analogues in a comprehensive study of the whole system, i.e. the network, alternator, turbine, governor, penstock, surge chamber and tunnel. The paper was perhaps a little vague on a number of points which the author had been at some pains to emphasise, namely, the decrement and limits of surge amplitude. He had yet to find a surge chamber designer or turbine designer who would give a specific answer as to the acceptable magnitude of these characteristics for surge chambers upstream or downstream of the turbine. With underground stations utilising tail-race tunnels under pressure, the need for surge chambers was a question on which the less experienced engineers had sometimes to be convinced. As far as he was aware, these conditions, or the conditions under which these downstream surge chambers became necessary, had never been defined, and perhaps the author could say whether the criterion relating to the penstock and machine-time constants for stability of governing in an installation with a free flowing tail-race could be correctly extended to include the time constant of the tail-race tunnel.

Mr. H. D. Morgan drew the author's attention to one case with which he had not dealt, namely, the case in which the main tunnel had a large number of intakes at intervals. He illustrated his points by reference to the Le Havre tunnel, where a very large number of shafts bring water in at intervals, making the mathematical treatment very complicated.

Mr. Oscar Elsden remarked that the first problem encountered in the design of a surge chamber was to determine the worst flow variations to which the system would be subjected, and it was refreshing to find that the author had devoted a fair amount of space to a subject which was virtually ignored in the majority of standard textbooks from which the ordinary civil engineer, such as himself, had to start. In his own experience (which was limited mainly to the Scottish stations) surge chambers had always been designed for full load rejection at maximum water level, and in some cases it had also been necessary to determine the down surge caused by full load rejection at minimum water level. Occasionally it had been necessary to consider overlapping or compound surges, such as were mentioned by the author and also described in a special paper by Monsieur Calame in the *Bulletin de la Suisse Romande*, May and June, 1934. It was necessary to take various assumptions for load thrown on, sometimes according to the wishes of the clients; but he suggested that the load-thrown-on assumption was of importance with a differential chamber, which showed to its best advantage when designed for only part-load thrown on. The maximum load change was in practice never complete and never instantaneous. The machines were idling under about 10 per cent of the discharge before they were loaded, and would return to this condition on abrupt rejection of load. Occasionally the idling flow was allowed for in the design assumptions, but in calculations the changes were usually taken as instantaneous. In the lower head stations, the area of the surge chamber was usually governed by the Thoma equation, and common practice was to adopt a factor of safety of about 2. For the higher head installations, the surge amplitude was often limited to about 15 per cent of the net head, and the chamber was often considerably greater than that necessary to secure stability alone. The author mentioned that negative pressure effects were as important as the positive pressure effects; the author's opinion might be amplified by saying that, from the civil engineering point of view, they were sometimes more costly to deal with. For example, the tunnel must always be kept below the lowest down-surge level and also below the corresponding hydraulic gradient. It was therefore necessary in certain cases to ensure that the down-surge never went below a certain level, because otherwise the tunnel gradient would become too steep for convenient or economical driving. Satisfactory conditions could usually be produced with a simple chamber, if it was big enough, but various attempts to economise had been made. Messieurs Calame and Gaden, in their well-known text-book, discussed other types, and the determination of their dimensions. Their methods were aimed at producing a chamber of minimum volume on the assumption that in an excavated chamber the cost was proportional to the excavated volume of rock. In these days of scarce materials, shortage of skilled labour and shortage of skilled designers, it was not a foregone conclusion that reduction of excavated volume would produce a proportionate saving in time or in cost, and a considerable saving in paper estimates was necessary to justify any complication in design. In recent years there had been consideration in special cases of the use of spilling chambers or chambers of variable section, but they had not been found to have any economic justification. The works necessary to carry the water from a surge chamber spillway to the nearest watercourse could be quite expensive.

For amenity and other reasons, surge chambers were usually formed by excavation. The excavation of the chamber was usually carried out from the tunnel beneath by raising a stope upwards to the surface. Stoping was a slow and somewhat hazardous operation, but this was to some extent true of shaft sinking, and the stope had the advantage of being self-draining and self-mucking. The stope also took advantage of the equipment already installed for spoil disposal from the tunnel. The stope generally formed a pilot shaft down which the material was shot when the chamber was finally excavated to its full size. The surge chamber was usually lined with concrete, which nowadays was often placed within continuously climbing shutters. This was a rapid and, on the whole, satisfactory method of lining the chamber, when this was of simple cylindrical form.

Mr. H. R. Lupton, observed that the author had mentioned, of course, that there were two different kinds of pressure disturbance. The first were the short-period disturbances which were dependent on the compressibility of the water and the elasticity of the containing surfaces, and the second were the long-period disturbances (which were the main subject of the first part of the paper) which would take place even if the water were incompressible and the containing surfaces rigid; and the actual effect in the end was a combination of the two. One got some error if one worked out the surges independently and then combined them wherever the relationship between heads, accelerations and velocities was not linear; so that he made a plea that the step-by-step method, which had to be used where the layout was very complicated, be used to include both the elastic waves and the long-period disturbances which were the main subject of the paper. It seemed to him that only a combined investigation of that kind could be perfectly safe.

Mr. S. P. Hutton, felt that all those present had found the paper a most interesting survey of this specialised subject. He had himself found it very stimulating, although the stimulus in his case had been to prompt him to ask some questions of the author.

Mr. Headland had already mentioned that most of the knowledge gained so far on

this subject had been from the practical experience involved in making step-by-step calculations and comparing the results with those actually obtained in the field. Relatively little work had been done in the laboratory, although it was known that there was a growing use of laboratory work. As Mr. Headland had mentioned, there must be limitations in this field, and he would like to discover the author's present opinions on how far small-scale experiments under controlled conditions in the laboratory could be of service to the design engineer.

The author had mentioned the importance of the inter-relation between the turbine governor and the surge tank characteristics. Had he ever encountered any resonance failures where back-lash in valves had tended to set up oscillations in the system in conjunction with the other factors already mentioned ? Certain valve designers on the Continent seemed to have gone to great lengths to operate valves directly by hydraulic means without any linkage or gearing or counterweights, and he wondered whether the reason for this rather expensive construction was merely to provide as compact a unit as possible or whether it was to avoid the possibility of any oscillations that might be caused by back-lash in operation.

Dr. O. C. Zienkiewicz said that recently he had had the opportunity, at Edinburgh University, of being in charge of an investigation into the fundamental aspects of pressure wave transmission through various types of surge tank. This had been a model experiment. Previous speakers had referred to models, and he felt that it was impossible to assimilate all the actions of a surge tank in one model ; but for the particular purpose of studying transmission of water hammer waves it was possible to obtain a model. In the investigation, orifice and differential surge tanks had been the main subject of research, and he hoped that this work would be published shortly.

It had been found, as the author stated, that by the graphical methods of Bergeron and by other methods of calculation it was possible to calculate with a very good degree of accuracy the transmission of pressure waves in all types of surge tanks. An accuracy of 2 to 3 per cent had been obtained even for orifice or differential surge tanks. Broadly speaking, it had been found that even with relatively small orifice sizes the transmitted pressures were not excessive for all but pressures due to instantaneous flow stoppages. The case of instant flow stoppage was obviously not a practical danger. Though sometimes assumed in design, the justification of this assumption lay in the fact that as long as the total time of closure did not exceed the period of the simple conduit the pressures produced would be identical. As far as the magnitude of the transmitted pressures was concerned, it could be shown that with closures taking a finite though small time, these might be reduced to a small fraction of their " instantaneous " values. Thus, for checking the efficiency of a surge tank installation in respect of the transmission of pressure waves, it was imperative to know the maximum rates of flow increase and decrease. It would be of great interest if the author could add to the list of operating conditions assumed by Continental designers some figures relating to this problem. It must be realised that these maximum rates were not necessarily related to the governing constants. Accidental gate movements might occur at much greater speeds, but even so would never reach the impossible " instantaneous " case.

The second reason for surge tanks, as stated in the paper, was the instability of governing which might occur with very long conduits. This was, he felt, a question of balance. Even in relatively short conduits it might be possible to introduce instability by too sensitive governing. There must be many practical cases of the borderline where the quite considerable cost of provision of a surge tank could be countered by the installation of less sensitive governing and larger inertia of the machines. He felt that the economics of such projects should be investigated carefully by both civil and mechanical engineers concerned.

Mr. Peter Linton believed that nobody would be misled by the few equations quoted in the paper into thinking that problems of this type could be solved by a few lines of arithmetical calculations. On the contrary, the types of surge tank proposed recently to cut down excavation costs required extensive step-by-step calculations even after their basic theory had been established. He wished to reinforce some of the remarks which had already been made in the discussion in connection with model tests. It seemed to him that one of the characteristic features of the average British engineer was his mistrust of mathematical methods. This might be due to his lack of experience in handling anything but the simplest differential equations, but he thought it was more probably due to a conviction that many of the assumptions from which mathematicians cheerfully constructed their theories did not always hold in practice. There was, of course, always the possibility of errors, either in the abstractions required to make the problem amenable to calculation, or in the extensive and often tedious numerical work involved, unless the task was entrusted to a specialist who could generally tell whether the answer was reasonable or not. Even he, however, would often have difficulty in convincing the engineer that the result could be accepted as correct without further so-called safety factors ; after all, heavy damage or even loss of life must be expected if a water power scheme was designed incorrectly.

There appeared to be a very strong case for the extensive employment of model tests in the design of surge tanks. The role of experiment in engineering had been the subject of several letters in recent issues of THE ENGINEER, and there seemed to be general agreement that results obtained from model tests were valuable even when they did no more than confirm and illustrate the mathematical calculations. In the present case, however, such tests could provide information over a much wider field. When applied to a particular installation, they would generally supply numerical results in a shorter time than the step-by-step calculations, especially when a large number of loading conditions had to be investigated. Models might be used on new types of surge tanks for which no theory had yet been developed. Even more important, however, was their application to determining the experimental constant in the surge tank equations.

Work in this field appeared to be in progress at a number of Continental laboratories, and it would greatly assist research in this country if the author could comment briefly on the methods employed and on the value of the results obtained in such model tests.

Dr. C. Jaeger, in a brief reply, felt that everybody agreed on the importance of studying very clearly the condition when taking load on ; and several contributors—among them Mr. Headland, Mr. Morgan and Mr. Elsden—had said that they considered the condition for opening even more difficult to satisfy than the condition for closing. Mr. Headland had referred to the faulty synchronising of turbines with the automatic closing of switchgears, circuit breakers, and so on. All these points had been duly considered, particularly by the Italian engineers, Scimemi and Ghetti, in their papers, which were mentioned in the bibliography at the end of the paper, and they had come to the conclusion that severe conditions should be imposed for the surge tank design, especially when those points had to be considered.

Mr. Headland had referred to the restricted orifice surge tank and the differential surge tank, and had asked why the Continental designers preferred the restricted orifice surge tank and the Americans were in favour of the differential. The American designers preferred the differential surge tank because they took into consideration only partial opening, i.e. the case of load being taken on slowly. On the other hand, most of the Continental designers would consider the most severe case, and the restricted orifice tank was far more suitable than the differential tank for that case.

The question of underground stations had been mentioned by several contributors, and he had been asked what was the limit between an underground station with no down-stream surge tank and a station with a down-stream surge tank. The limit was really set in most cases by the problem of governing. If the ratio of the lengths of the upstream and downstream galleries and tunnel to the head was more than a certain figure, which also depended on the velocity in this tunnel, then a surge tank might be necessary and indispensable for better regulation. There were many cases where it was difficult to say whether the station could be built without a surge tank or must be built with a surge tank. The decision was very difficult because in most cases which were at the limit the surge tank was a tremendous construction ; in many cases the excavation for the down-stream surge tank was as great as, or even greater than, the excavation for the total power station itself.

He thought that to-day the technique of model tests had been evolved to such an extent that one could rely on the results given by them. There were, of course, many difficulties. One was that the Reynolds Number in the prototype and the Reynolds Number in the model tested might be quite different, and therefore one might have in some instances a turbulent flow in one case and a non-turbulent flow in the other. Model tests permitted the introduction in the analysis of points which could not be introduced in the equation. One point which had been mentioned, and which was very important, was the energy loss which was produced in any surge tank when the water was diverted from the direct flow to tunnel to the pipe into the surge tank. This was mainly a diversion at an angle of 90 deg., and the losses produced by this diversion of the flow might be very considerable and added also to the stability. But he must add that it was difficult to represent on a model the true condition for stable oscillation. If there was no special arrangement made to reproduce the curve representing the steady output of energy, then the model would prove that any oscillation was stable. Therefore, it was necessary to add to the model a special gadget or special arrangement to superimpose on the oscillation of the model the condition of stable output, and this was the main difficulty. Some special electronic gadgets had been devised by several laboratories to superimpose on the hydraulic model this condition of stable output of energy.

Double Rate Shock Absorbers

A brief description is given below of two proprietary oleo-pneumatic units, each of which has been developed to provide two rates of air compression during closure. One of these units has been designed to meet the dynamic loading peculiar to the nose-wheel leg of tricycle aircraft suspension. The other is a long-stroke main leg in which it is desirable that the cycle of closure and extension shall be of high frequency in order that naval aircraft when parked are outside the influence of deck movements.

IN the design of oleo-pneumatic shock absorbers for aircraft there are two applications which present special problems. The nose-wheel in a tricycle layout is probably the one of more general interest. Here the leg is subject to dynamic loading quite different from that imposed during any of the possible impact loading cases it can experience during touch-down. These result from the pitching tendency

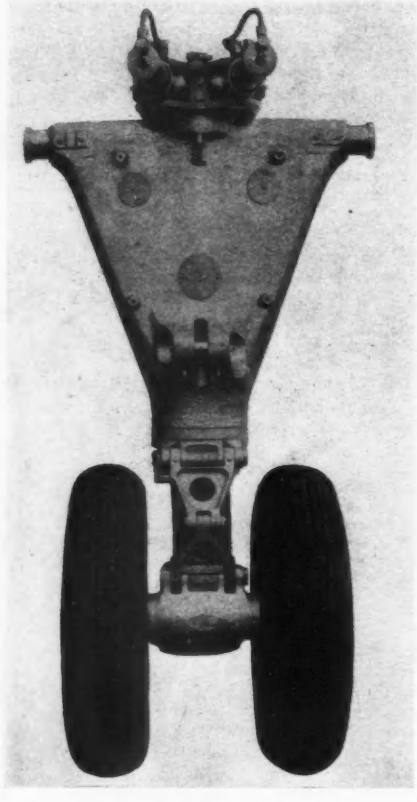


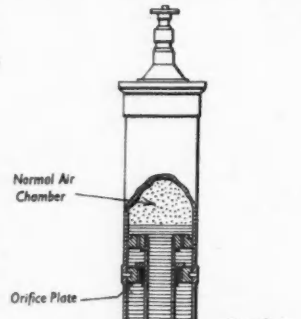
Fig. 1—Nose Wheel Installation on "Victor" Bomber

which arises, depending upon the geometry of the suspension and the Polar moment of inertia of the aircraft—when the brakes are suddenly applied on the main legs.

The velocities of nose-leg closure occurring due to this pitching moment being considerably below the order of those for which it would normally be designed for the landing case, largely prevent the oil from contributing to the reaction. Furthermore, little energy is dissipated and the full reaction thereby depends solely upon the pneumatic characteristics of the leg. Interpolation of the initial curve in Fig. 1 indicates the unsuitable nature of the air compression characteristics and shows that normally very high reactions must inevitably develop rapidly towards the end of the stroke. To meet this particular requirement and without greatly increasing the size or stroke of the unit, Electro-Hydraulics, Ltd., has developed the "Duplex" oleo-pneumatic leg. It is incorporated in the nose-wheel installation illustrated in Fig, 1, which is that of the Handley Page "Victor" bomber.

It is basically a conventional oleo-pneumatic leg,* as shown in Fig. 2, into which a high-pressure air chamber has been introduced at the lower end of the sliding member. A floating piston seals this chamber from the oil which communicates through the hollow piston rod with the upper air chamber. In operation the floating piston is held against its stops until displacement of the piston integral with the sliding member raises the pressure within the upper air chamber to that of the high-pressure air. Over the remainder of the stroke compression of the air in both chambers then proceeds simultaneously, giving the effect of a decreased compression ratio. The accompanying diagram in Fig. 2 illustrates the reaction characteristics of the unit supposing that closure takes place very slowly and hence pneumatically. It is shown that a closure cycle can be arranged such that the two shaded areas in the diagram are equal and hence in effect a mean linear reaction is obtained over the interval between static closure and the dynamic braking closure positions.

It is of interest to recall here the Dowty "liquid spring" nose-wheel unit recently illustrated in these columns (*loc cit*) which, depending on



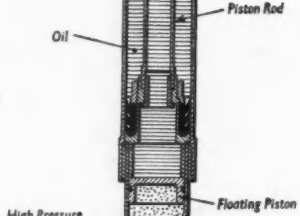


Fig. 2—Nose Wheel Oleo-pneumatic Capsule

the admission of a ram in a sealed cylinder containing oil, also exhibits a linear reaction/displacement characteristic when undamped.

Long Stroke Double Rate Unit

The other development to which we made earlier reference arose as the result of the persistent trend in naval aircraft towards higher vertical descent velocities. This condition is influenced not only by the landing techniques demanded in carrier operation, but by the vertical displacement of the deck itself. Vertical velocities as high as 20ft per minute must now be allowed for in the leg design of naval aircraft as against 10ft per minute for civil aircraft, where figures as low as 2ft per minute can be regularly attained under normal conditions.

The much longer stroke required in such units to restrict the maximum reaction factor leads to a low rolling frequency. It is necessary, however, if the aircraft when parked is not to be easily excited by deck displacements, that the aircraft motion be of small amplitude and high frequency.

Consequently one such unit designed to have a high aircraft rolling frequency with a long stroke has recently been developed by British Messier, Ltd. The leg has a stroke of 20in. ($\lambda=3$) and is illustrated in Fig. 3 and diagrammatically

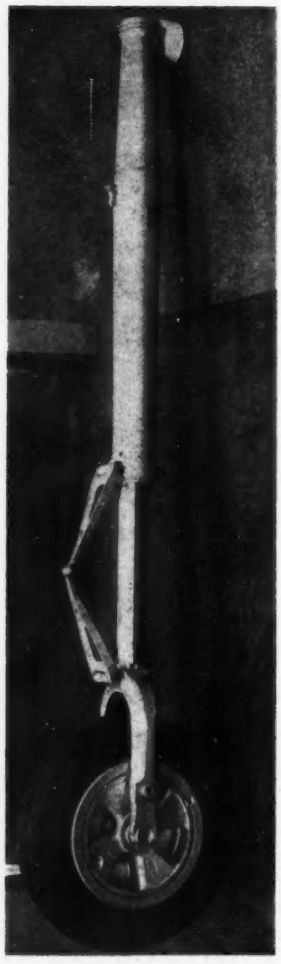


Fig. 3—Long Stroke Leg for Naval Aircraft

in Fig. 4, in which certain minor damping orifices have been omitted.

In this unit the greater portion of the energy to be absorbed is dissipated into the oil in the normal manner, the remaining energy being stored by two pneumatic "springs" in series. One "spring" is just capable of extending the leg when the ground reaction is completely removed, the other having a higher rate and being strong enough when approximately half closed to support the static aircraft weight. The two spring rates are obtained from the same pneumatic chamber by changing the rate of oil displacement—the compressing agent—at some predetermined stage of the closure stroke.

During dynamic closure, energy is dissipated by oil passing through the closure orifices located in the floating damping head, from volume *B* to volume *C*.

During the first stage of closure the air in

* "50 Years of Undercarriage Development," Parts II and III, THE ENGINEER, August 28th and September 4th.

volume *A* is only relatively slightly compressed by the rise of fluid level which results from a fluid displacement equal to the annular volume of the sliding tube admitted.

During the second stage the rate of oil displacement into the air chamber is greatly increased by the bottoming of the floating piston on stops in the sliding tube, and its vertical displacement thereafter.

On recoil, as the air expands oil is forced through the recoil orifices located in the floating damping head, from volume *C* to volume *B*. The comparatively low energy stored pneumatically to ensure an adequate recoil velocity

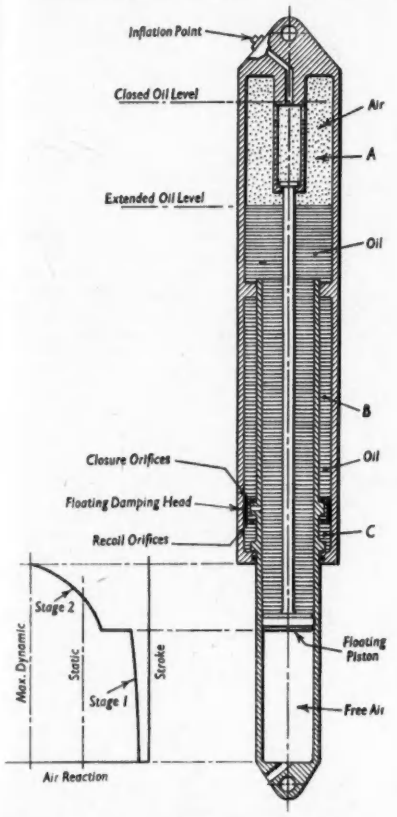


Fig. 4—Diagrammatic Arrangement of Long Stroke Leg

is thus dissipated into the oil. The recoil orifices are such that the leg during recoil will not extend beyond the point where the spring rate changes.

Closure and extension of the shock absorber, resulting from deck movement exciting the aircraft, is limited by the rate of the high rate spring. It is possible, therefore, to store only a small amount of energy in the shock absorber. It will be realised that the aircraft would be inherently stable when parked on a rolling deck, but would also be capable of landing at a high descent velocity without severe rebound. The simple construction and inflation procedure of this design is claimed by the makers to compare very favourably with the more conventional shock absorber designed for these service conditions.

GOLD-FILM DE-ICING FOR WINDSCREENS.—It is learned that the Triplex Safety Glass Company, Ltd., is now installing equipment at its King's Norton, Birmingham, factory to produce flat, gold-film-coated glass in sizes up to 3¼ft long by 2ft wide for aircraft windscreens. The thickness of this electrically heated gold de-icing element will be approximately 0·0000002in. The voltage applied will depend on the size and shape of the glass to be heated, but will be much lower than that required by any previous transparent conducting film. The gold film can be coated on the inside surface of one of the two outer glasses of the complete laminated windscreen. The coated glass may be of any thickness between ¼in and 1in, but the most satisfactory results were obtained using glass not exceeding ¼in thick. It is anticipated that flat gold-film glass panels will be available for service aircraft by the beginning of next year. By agreement with the Plessey Company, Ltd., the Triplex Safety Glass Company, Ltd., will supply complete aircraft wind shields, including the associated control equipment.

"The Electrical Revolution"

At a meeting of the Supply Section of the Institution of Electrical Engineers on October 28th, Dr. L. G. Brazier delivered his inaugural address as chairman of the section. The first of the following abstracts from Dr. Brazier's address describes an interesting experiment in which the speaker demonstrated the release of electron energy from a glass disc in which electrons, previously energised in a particle accelerator, had been trapped. The second abstract is concerned with some of the possibilities of the "electronic brain."

"Packaged" Electron Energy

When a cable breaks down, the dielectric deterioration often takes the well-known form [shown on a lantern slide] which is known as "treeing." The pattern is formed by a carbon track which in the case of a paper cable runs from layer to layer of the dielectric. Twenty years ago my very good friend, and at that time my colleague, Denis Robinson, attacked the problem of why cable deterioration should take this rather peculiar form. He was able to show the exact mechanism which leads to these tree formations, in a way which has found general acceptance since then. I recall this to you as a thread on which I can do myself the pleasure—in which I hope you will join me—of carrying out, or attempting to carry out, in this theatre and under the portrait of Faraday, an entirely new experiment. The experimental demonstration is certainly new, and I believe the effect underlying the experiment is new.

Dr. Robinson has for some years been occupied in America in applying to very-high-voltage scientific equipment the increased electric breakdown strength of gas under pressure, which was first used in the development of the high-performance pressure cable. As a result of the pioneer work of Professor Van de Graaff and Professor Trump at the Massachusetts Institute of Technology. it has become possible to compress the formerly bulky Van de Graaff high-voltage d.c. generator within an enclosure which can be raised to a high pressure, and in this way it is possible to produce in a comparatively compact form an apparatus which will deliver an electron beam of 2,000,000 or more volts energy. That is to say, the electrons have been accelerated by a potential fall of 2,000,000V. A parallel beam of elementary particles of such energy represents an entirely new tool available for the use of man. The exploitation of these possibilities is due very largely to the work of a company which was formed specially for this purpose by Professor Van de Graaff, Professor Trump, and Dr. Robinson. These high-voltage electrons are used, for example, for the bulk sterilisation of foodstuffs and drugs, and when converted to X-rays they are used in the treatment of cancer. I mention these as further examples of the manifold uses of electricity in a high-standard-of-living civilisation.

In conversation with Dr. Robinson this summer, he told me of his results, and with this stimulation we devised together the experiment which I shall try to carry out.

A beam of electrons emerging with an energy of 2,000,000V has for our experiment to-night been directed on to this disc of boro-silicate glass. In this dense material the electrons can only penetrate about ½cm, or about half the thickness of the disc. Having penetrated half-way through the disc the electrons are, as it were, entrapped by the high resistivity of the glass. In this state the disc has been flown across the Atlantic for our meeting to-night.

This glass disc which I am holding in my hand represents, therefore, in a way a package of high-voltage American electrons. Certainly the electrons were ejected from a hot cathode in Cambridge, Massachusetts. They were accelerated to high speed and driven by their own momentum into the glass ; and "encapsulated" in the glass they have arrived here.

We are not, of course, talking about various well-known ways in which energy can be transported in a dielectric. The dielectric is not storing energy as in a capacitor, since there are no electrodes on the surface. The dielectric is not polarised as in an electret, since there are no opposing poles on the opposite faces. It is no question of a surface charge, since I can wipe the faces freely. You will notice, however, that I am taking care not to scratch or prick the surface, since if I were to do so I should certainly receive an unpleasant and perhaps dangerous shock. In this respect the disc can be regarded as a pocket-size electron bomb.

Well, what will these American electrons do for us now we have got them here in London ? I hope to give you visual evidence of their existence. First of all I am going to support the disc in this stand and then prick the surface.

[There was a bright flash as the speaker pricked the surface and the electrons were released.]

If the needle point which pierces the surface is connected to a voltmeter it registers a discharge voltage of nearly 2000V. You will therefore understand my anxiety, that I mentioned just now, about receiving an electric shock from one of these discs.

I want now to repeat this experiment on a second disc, arranged behind a lens, which will project an image of the disc on to the screen. The image is, of course, only momentary, but I hope that some detail which cannot be seen by direct vision will be visible.

[Finally, the speaker showed a lantern slide from a photograph of the instantaneous discharge that was obtained in one of the earlier tests.]

The same tree-like pattern found in cable deterioration pervades all these discharges. The trunks and main branches of the visible discharge leave behind them a tree pattern of hair cracks in the glass. This pattern is, however, not so extensive as the visual pattern. Both the visual pattern and the hair cracks are wholly within the interior of the glass, except at the position where the surface was pricked. They lie in the plane reached by the electrons during the bombardment. The pattern of hair cracks lies congealed in the glass like the flowers in a Victorian paper-weight.

Before leaving this subject I feel I should put in a word of caution concerning the rather free phraseology that I have permitted myself in describing the state of the electrons within the glass. I have no doubt that the atomic and theoretical physicists will demur and qualify. Almost certainly the electrons must be attached in some way to the atomic structure, but the mechanism of their release at the instant of discharge is obscure. It cannot be assumed that the visible discharge is a purely electrical effect. I know, for example, that an electron at one instant cannot necessarily be continuously identified with an electron existing at a later instant. Nevertheless, I believe that, in spite of all these difficulties, in the end what I have said to-night will in a broad way prove to be justified.

Electronic Calculating Machines

Modern study has shown that a calculating machine must be organised in three basic sections. Besides a sequence controller and a unit for carrying out arithmetical operations, the machine must contain a store or library of information or instructions, which, in conjunction with the results being obtained by the machine, will always provide a positive instruction for the next operation to be carried out. Just as information can be organised on a numerical basis represented by on-off switches working in a binary code, so the comparisons, decisions and instructions can be organised on a "go" or "not go" basis which can equally be executed by on-off switches. The elaboration of the whole process is of no account when the steps are carried out at the rate of a million a second. It is extremely high speed which is revolutionising the work to which an electronic computer can be put. But the ultimate marvel of electronic calculation has not yet been worked out even if it can be seen with certainty only a little way ahead.

With equipment of the kind that has been sketchily described there is no difficulty in feeding into the library the results obtained by the machine. These then become the basis of subsequent decisions and instructions to the operating section. Thus the working of the machine is not controlled by a rigid programme supplied beforehand from the outside, but is determined, to a great or lesser degree as desired, by the results the machine itself obtains. It is

this ability of the machine to run its own course once the general objective has been set, dependent primarily on results obtained by its own operations, that has earned for it the title " electronic brain " and has posed the question—Can these machines think ?

I am sure that everyone here to-night feels that he knows the answer to this question ; but the more carefully it is examined the more difficult does it become to pin-point a specific example where the answer is clear cut. It is not that the machines can learn information merely to repeat it. In fact, a machine can be arranged with the ability to organise new information meaningfully and to select alternative modes of behaviour on the basis of this organisation.

One of the classical experiments in biology on animal intelligence consists of placing a mouse at the entrance to a maze with a bait of cheese at the centre. At the first attempt it takes a long time by random trial and error to reach the centre, but each successive trail is shorter until finally the mouse invariably takes the shortest route. A mechanical mouse complete with electronic computer has been constructed which exactly duplicates this performance. As each preliminary trial proves abortive the information is entered in the electronic library and is used to prevent that particular turning being taken on subsequent trials. The first trial takes a long time. Successive trials are shorter, until finally the mechanical mouse always takes the shortest route. If the biological experiment gave evidence of an animal's intelligence, what are we to say about the results with the mechanical mouse ?

Does the machine " think " in such exercises ? As Oettinger has pointed out, it is no reply to say that the machine can answer certain questions intelligently, but cannot deal with situations outside its range, since this is in fact not a denial of machine intelligence, but an admission of its existence, though in a limited form. A machine can even be programmed to react to expressions of approval or disapproval. Such a machine can be taught different modes of behaviour. Listen to the anthropomorphic language of Oettinger describing the training of his machine.

" As the training proceeds," he says, " errors become less frequent, and the learned response may be initiated by a progressively weaker stimulus." As the training proceeds further he says, " the need for approval diminishes." After a behaviour habit had been formed it was desired to change it. The unwanted habit persisted for some time, but, as he reports, " one last sharp disapproval finally inhibited it."

Training a machine requires, we are told, as much patience as the training of animals. But fortunately one machine can be set the task of training another machine. Machines trained in a behaviour habit in this way are, in fact, exactly reproducing the classical biological experiments on conditioned reflexes.

There is an astonishing point of similarity between the detail mechanisms of the electronic calculator and what is known of the human brain. It has been known since the last century that the nerve fibres (the connecting " wires " of the brain) work with an " all or none " action. The nerve does not transmit a signal graduated in strength. When stimulated it either does or does not fire a standard electrical pulse. The connection is not permanent. The synapse is a relay which may or may not fire off standard pulses in the adjoining nerve depending on present and past stimulations. The brain is a vast multiplicity of interconnected " on or off," " go or not go " elements. The brain works on the binary system.

It is remarkable, or perhaps later philosophers will find it inevitable, that man without conscious and imitative intention has devised a machine which in the working of its elements imitates so closely the human brain. The parallel is so close that serious work is now in progress to use simple assemblies of a small number of binary units to study the method of working of the human brain. Grey Walter has reported that with the simplest of such models a large number of well-known normal or pathological mental behaviour patterns have been reproduced, and that the model will show behaviour patterns which, he says, " are so complex that in practice the future of the system cannot be predicted accurately from external knowledge of its past." Here we have a reversal indeed. The brain is not studying the machine. The machine is being used to study the working of the brain.

The electronic calculator has already opened up new fields and methods of mathematical calculation. It may well in the future open up new fields and types of mathematical and scientific reasoning, the form of which we cannot now foretell. There is another application, however, which will have an immediate impact. Elementary, special-purpose electronic calculators will be used for the automatic control and operation of manufacturing plant. Modern theories of control and servo mechanisms in conjunction with the electronic calculator make it possible for most human interventions in a manufacturing process to be replaced by an automatic machine. It is a question of balancing the capital cost of the machine against the running cost of the man. Increasingly the automatic machine will be found preferable. The process has already begun. In America the annual statistics show that, out of the total expenditure by American manufacturing industry, the proportion now spent on electronic devices has risen to 20 per cent. Already there is talk of the completely automatic factory. We are on the brink of a second Industrial Revolution. The first replaced man's labour by mechanical energy and, in its later stages now in progress, by electrical energy. The second revolution will replace his mental operations by machine intelligence. More and more the working population will be engaged not on the operation of manufacturing plant, but on the design, construction and maintenance of automatic machinery.

Magnetic Amplifiers*

By J. F. COALES, O.B.E., M.A., M.I.E.E., F.Inst.P.

THE use of the non-linearity of the magnetisation curves of transformer cores appears to have first been used in this country by J. D. Coales [the author's father] for testing large power transformers in 1907–8.† This and bridge methods employed more recently work on the change with magnetising field of the incremental permeability of the magnetic core. The advent of high-permeability magnetic materials with a sharp knee in the magnetisation curve has resulted in the development of the transductor, which essentially consists of two cores, which are alternately driven far into saturation in each half cycle of the supply frequency. These transductors are essentially d.c. amplifiers, the magnetisation of the cores being biased by input windings connected in series, the excitation windings being in opposition. The operation of a transductor is similar to that of a pair of grid-controlled rectifiers in that, as soon as saturation of one core is reached, the inductances of the windings on it fall to a low value and the currents rapidly increase, driving the core far into saturation. The impedances of the windings must then remain small until the current through them has dropped to a very small value, which, since the impedance is small, can only result from the excitation e.m.f. dropping almost to zero.

Another important principle in the operation of transductors is that the current through the load is only significant when one core is saturated and the other not, in which case there is tight coupling between the input and excitation circuits and ampere-turn balance must be maintained between them. Thus the current gain of a simple transductor is always equal to the ratio of the number of turns on excitation and input windings and the transductor is equivalent to a current amplifier of high gain with 100 per cent negative feedback. This fact results in a highly linear relationship between input and output, but a low power gain.

As might be expected the power gain can be increased by feeding the rectified load current back to the input in the positive sense. This process is known as self-excitation and results in some reduction of the linear range and increased drift. There is, however, considerable improvement in transient response since, independently of the amount of feedback employed the time-constant of the transient response is almost directly proportional to the current gain, whereas the power gain is proportional to the square of the current gain. It has been shown that provided 100 per cent self-excitation is required it can be more simply achieved in the case of parallel-connected transductors by the use of rectifiers to suppress, in each half-cycle, the excitation current in the windings which will not be saturated.

Self or auto-excitation results in increased standing current and, as might be expected, this results in reduction of stability. It is easily shown that the chief cause of drift is change of the rectifier characteristics and with the best available at present the smallest input signal that can be discriminated with this type of transductor is 10^{-7}W.

The simple two-core transductor does not distinguish between positive and negative input currents and in order to do this a push-pull arrangement must be used. This arrangement results in some improvement of stability and the smallest input power which can be discriminated is of the order of 10^{-9}W.

It is then shown that by connecting the load to additional windings magnetically similar to the input windings and suppressing the even harmonics (which would otherwise be induced in the input circuit) by means of a high impedance, these harmonic currents can be forced into the load circuit which then has no standing current, but, since ampere-turn balance must be maintained, has the same signal current as before. This results in a very great improvement in stability and by the use of elaborate valve circuits a short term stability of 10^{-18}W can be achieved. If, however, the magnetic modulation is to be followed by a magnetic amplifier, since the greatest gain that can be achieved in the modulator is about 10^3, the best stability that can at present be achieved with an all-magnetic system is of the order of 10^{-12}W.

In general, unless a magnetic modulator (inverter) is followed by a thermionic amplifier, it is variation of the rectifier characteristics which limits the smallest signal which can be discriminated. Thus, the crying need is for improved rectifiers, especially for small forward currents. Improved magnetic materials will, however, give some improvement, a sharper knee giving a greater linear range and reduced hysteresis, and reduced eddy current losses giving reduced standing current. Reduced standing current is of great importance when, as is usual, self or auto-excitation is used. In ordinary transductor circuits the lowest power levels are many orders above the limits set by magnetic noise and in general the effect of changes in the core material is almost certainly negligible compared with the effect of changes of rectifier characteristics. Thus we want magmetic materials with :

(1) Reduced hysteresis and eddy current losses to give lower standing currents ;

(2) A sharper knee in the B–H curve to give a longer linear range ;

(3) Greater slope in the unsaturated state to give greater gain with self or auto-excitation ;

(4) Less slope in the saturated state to enable a greater control ratio to be used which, in turn, allows $R_A/\omega L_A$ to be increased and so the time-constant can be reduced ;

(5) Increased maximum induction so that greater output powers can be obtained for same core size ; and

(6) Reduced cost.

We also want rectifiers with :

(1) Greater stability of characteristics during life and for changing temperature ;

(2) Increased back resistance ; and

(3) Reduced forward resistance. The requirements (2) and (3) imply a sharper knee at cut-off.

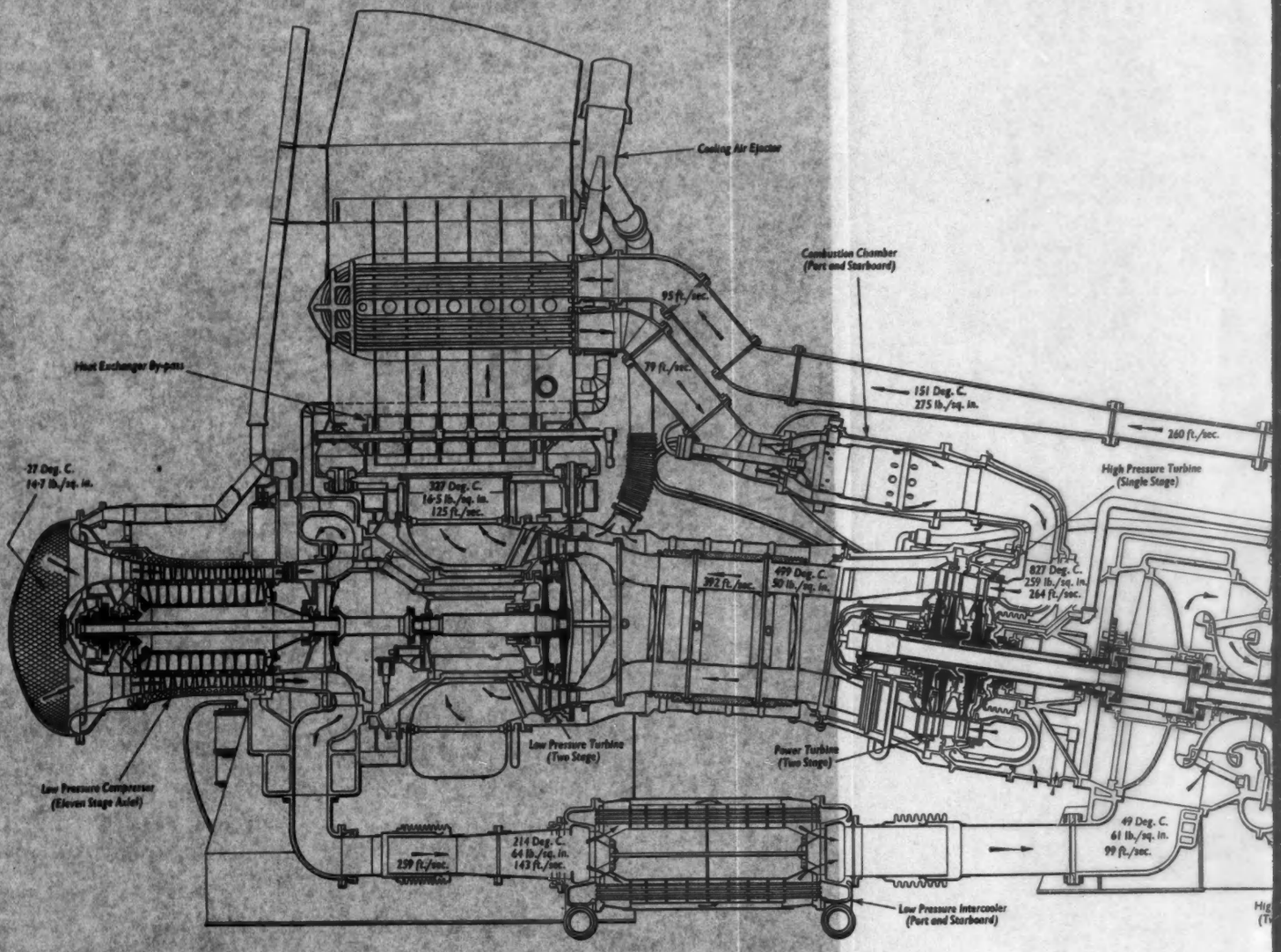
Unfortunately, the magnetic materials suitable for transductors are expensive and reduction of cost is an urgent need. Fortunately, developments are already in hand which should make possible the use of composite cores of which only a fraction has to be of the special transductor material and this may well open up a new field for economy in transductor design.

* Summary, Chairman's address, Measurements Section, Institution of Electrical Engineers, London, October 20th.

† Coales, J. D., " On a Method of Using Transformers as Choking Coils and its Application to the Testing of Alternators," *Journal I.E.E.*, 42, 1909, page 412.

"R.M. 60" MARINE GA

ROLLS-ROYCE, LTD., DESIGNERS AND



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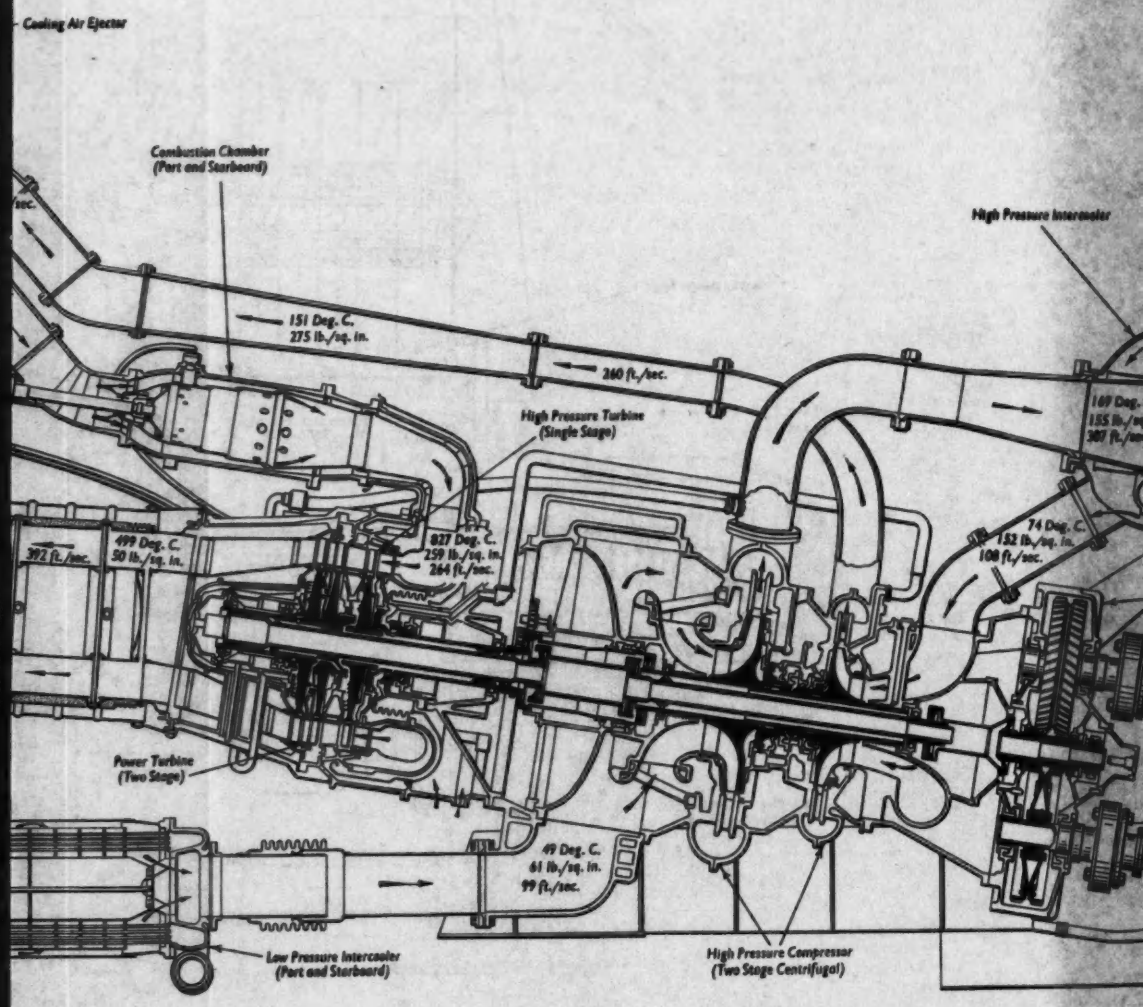
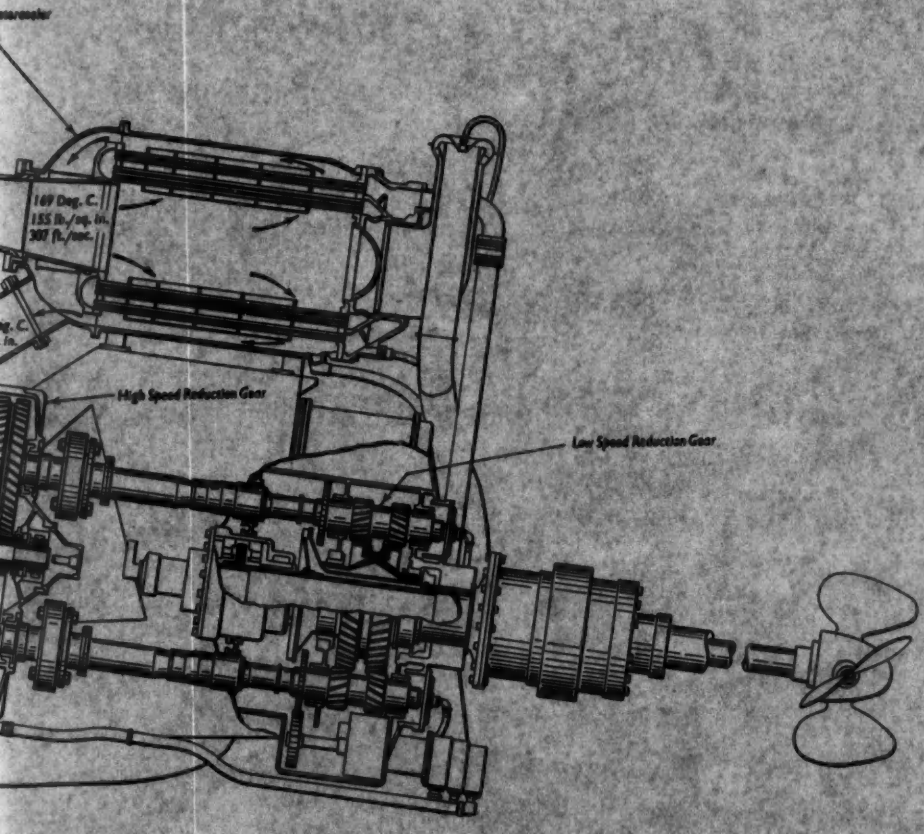



169 Deg. C.
155 lb./sq. in.
307 ft./sec.
High Speed Reduction Gear
Low Speed Reduction Gear

Present Trends in Surge Tank Design

By Dr. C. JAEGER*

The reason why load changes on the electric grid are the prime cause of surges is explained. The basic assumptions adopted for surge calculations by Italian, Swiss, French, and British engineers are reviewed, and it is shown that, in spite of many apparent disparities on special points, there is widespread agreement on fundamental questions. The interaction of surges, water hammer, and turbine governing is discussed in the light of the most recent tests on large power stations and of the results of modern theories, and the importance of the influence of water hammer on surge tank design is considered together with the special case of surge tanks connected to feeder canals.

Introduction

Surge tanks are usually associated with conventional hydro-electric power developments incorporating surface power-houses. In recent years many underground power stations have been built, and they, too, require surge tanks, sometimes giving rise to new and difficult hydrodynamic problems of their own.

Considerable changes in the demand for energy may suddenly occur in the electrical distribution lines and whole power stations may suddenly be cut off the grid or thrown on to it. At the present time no method has been found which would be capable of dealing with these sudden load changes on the electrical grid itself, in which there are inherent problems of stability. Ultimately, the full impact of these variations of energy demand is thrown upon the hydraulic system, where disturbances are bound to occur resulting in variations of pressure and discharge.

It is possible by measuring the pressure variations at the lower end of the pipeline to follow the effects of unsteady load on the hydraulic system. Two different types of pressure wave will be observed : (1) waves with a short period of a few seconds, which are elastic shock waves that can bring about elastic deformations of the pipeline wall and of the water column itself, and which are known as water hammer ; and (2) waves with a longer period—about 100 seconds to 500 seconds—which are synchronous with the surges in the surge tank.

Evidently the whole hydraulic system has to be investigated in regard to both types of pressure wave.

Notation.

a—Constant
b—Constant
C_1, C_2, C_3—Constant terms in linear differential equation of surges
D—Diameter of surge tank
D_1—Diameter of outer reservoir
D_2—Diameter of inner riser
F—Horizontal area of surge tank
F_1—Area of outer reservoir
F_2—Area of inner riser
F_{Th}—Value of F for condition of Thoma, area of Thoma
f—Area of cross section of pressure tunnel
H—Gross head
H_e—Net head
$h_v = H_e/z^*$
$k = dN/dN_r$
L—Tunnel length
N—Output of turbines, load of power station
N_g—Constant output, steady load, $N^* + \Delta N$
N_r—Load of larger grid
N^*—An initial load of turbines before an abrupt change
n—Safety factor
P—Constant in friction loss formula
Fw^2—Friction losses in tunnel
Fw_0^2—Friction losses at velocity of steady flow
$p = P/Z_e$
$p_0 = Fw^2/Z_e$
Q, Q^*, Q_0—Discharges through the turbines
R—Constant in restricted orifice formula
Rv^2—Additional friction losses in restricted orifice
r—Root of characteristic equation
r_0—Relative value of throttle losses
T—Period of surge oscillation, $2\pi\sqrt{\left(\frac{L}{g}\cdot\frac{F}{f}\right)}$
t—Time
$v = dz/dt$
v_0—Velocity in surge tank for $Q = Q_0$
w—Velocity in tunnel
w_0—Velocity of steady flow, Q_0/f
$w_0^2/2g$—Velocity head
$x = Fw_0^2 + z$
x_{max}—Amplitude of stable oscillations
Z_e—Maximum surge, $w_0\sqrt{\left(\frac{L}{g}\cdot\frac{f}{F}\right)}$, neglecting friction losses.
z—Oscillating level in surge tank above static level
$z_0 = -Fw^2$
Δ—Decrement, $x_t + {}_1/x_t$.
η_t, η_0—Efficiency factors of turbine and pressure pipe
θ—Relative value of closing time
ρ—Relative value of pipe characteristic
τ—Closing time of gates

* Consulting engineer, English Electric Co., Ltd., Rugby.

The upstream pressure tunnel is not usually able to withstand high pressures, and a surge tank will be the best protection against water hammer penetrating the tunnel. It is generally built at the downstream end of the pressure tunnel, upstream of the steeper steel pipeline or penstock which transmits the full available head. Protection given by the surge tank against negative pressure drops may be as important as that against positive pressure rises.

In addition, the surge tank makes possible a reduction in the length and thickness of the costly high-pressure steel penstock, and also permits stable regulation of the turbine, which may become impossible with a longer pipeline.

When rejecting or taking on load the surge tank will either accumulate water or, on the contrary, will deliver previously accumulated water, thus working as a compensating reservoir. The level variations in the surge tank have the effect of accelerating or decelerating the flow of the water masses in the pressure tunnel, until a new state of equilibrium with steady discharge is reached. The functions of the surge tank, therefore, are manifold.

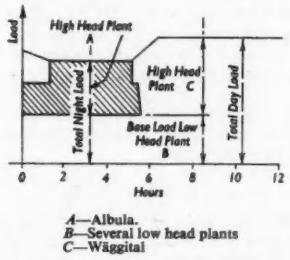
If the surge tank is on the downstream side of the turbine similar problems will have to be examined. It will be found that, in most cases of underground stations, a downstream surge tank is indispensable for regulation of the turbine, and for the avoidance of excessive variation of pressure on the downstream side.

The aim of this paper is not to reproduce the well-known elementary theory of surge tanks, but rather to disclose some modern research where the surge tank is considered as a most important element in the chain of mechanisms for obtaining a quick and simple adjustment of the load. The paper is to some extent a counterpart and a supplement to a recent paper by Dennis (1953).†

Loading Conditions to be Adopted

Wise choice of the type of surge tank is only part of the designer's work. It is most probable that definition of the conditions under which the turbine is loaded will require considerable thought and discussion.

In recent publications the fact has been stressed that loading conditions are becoming increasingly severe. At the same time there is a natural tendency to limit the margin of safety to the lowest permissible value, and to reduce the cost of every item, and especially the surge tank as being a feature of considerable magnitude though not actually productive of any energy.



A—Albula.
B—Several low head plants
C—Wäggital

Fig. 1—Distribution of Load on the Three Power Stations A, B, and C

A typical example of what may take place owing to changing conditions on the electrical network is the accident which occurred at the Albula power station (Jaeger, 1948). This plant was built by the town of Zurich between 1907 and 1910, and was equipped with eight Francis turbines of 3000 h.p. each. The surge tank was correctly designed for rejection of the full load, but it was assumed that the load would be taken on progressively by opening the eight turbines in succession, one after the other. The load on the network of the town of Zurich was then developing rapidly and, in 1926, the Wäggital power station was built with four generators of 16,500kVA at Rempen, and four similar units of 16,500kVA at Siebnen. The Albula station had to meet unexpected load variations when the other more powerful station was taking load on or off. The Albula surge tank was unable to deal with the new conditions and, finally, the pipeline burst owing to unfortunate circumstances of load shedding in another part of the grid.

Fig. 1, which reproduces the actual load variation which provoked the accident, shows that Albula *A* had to take over rapidly from Wäggital *C* at about midnight ; at 5.30 a.m. the load on Albula was thrown off abruptly, causing dangerous positive and negative surges in the Albula surge tank. The surge tank had to be designed anew and enlarged so as to be able to stand up to the far more severe loading conditions of the expanding grid.

At the time when this accident occurred, the Innertkirchen power station of the Oberhasliwerke was being designed by Dr. A. Kaech. The lesson learnt at Albula, through hard experience, was not neglected, and steps were taken to ensure that the Innertkirchen surge tank would be able to deal with exceptional cases of superposition of surges. Furthermore, the damping of the surge oscillations is extremely efficient, and suppresses those surge oscillations sustained for an undesirably long time which are characteristic of many other surge tanks.

In a recent paper, Scimemi and Ghetti (1951), analysing Italian experience, arrive at very similar conclusions. Loading conditions prescribed by the experienced customer are also increasingly severe, especially when the customer has had a wide experience of operating a large electrical grid. For definition of loading conditions, the design engineer relies on the experience and opinion of engineers who have been operating large grids over a long period of time. The present endeavour is to disclose the most recent tendencies in design of surge tanks as the result of this experience gained in the operation of large grids.

There is no doubt that any surge tank might have to face the sudden closing of all the turbines from full gate if a short circuit occurred while the power station was running at full load.

It is estimated by Electricité de France that this position will occur approximately once a year. To the author's knowledge, all surge tanks in important power stations satisfy this condition. Alternatively, provision is made for spilling when the water rises above a predetermined level.

Until recently it was accepted that the conditions for taking on load were in the hands of the supervisor of the station. It was considered possible to foresee the magnitude of the maximum load to be carried, owing to demand by big furnaces, large mills, heavy trains, and so forth.

Most of the specialists to-day consider that this reasoning does not cover the more dangerous cases. When several stations are connected to a large electrical network, it is always possible, because of accidents or a short circuit, that one particular station may be isolated automatically —or may have to be isolated suddenly to prevent the trouble extending to other parts of the electrical network—and that it may, therefore, have to take on load suddenly. So long as a turbine is not completely shut down but is only in the act of closing or running idle, it can be reopened suddenly to full gate. The loading conditions for load increase will, therefore, have to be examined in regard to the possible connection and disconnection of entire power stations belonging to the same general network.

There are many other causes of dangerous surges. A station may be losing load, with the turbines closing, and the water beginning to surge in the tank. If load is put on again, interference of oscillations will occur, and the danger of increased surges, through superposition of oscillations, is greatest if the switching-on of the load occurs when the water in the surge tank is again level with the water in the reservoir.

The reverse conditions may also occur : the machines may shut down suddenly soon after taking on load. There is no means of preventing such an occurrence. The downward surges may be even more dangerous than the upward ones.

This superposition of oscillations may happen at any level in the reservoir, and both the positive and negative maximum surges have to be investigated.

Superposition of opening-closing and closing-

† An alphabetical list of references is given on page 643.

reopening movements of the turbine gates were investigated on the model of the Innertkirchen surge tank which was finally designed to deal with any possible combination of surges.

The Loch Sloy tank (maximum reservoir level 935ft) has been designed on the assumption that four turbines being on full load may close, and two turbines may reopen to full load when the water in the reservoir is at a level of 830ft or higher. If the reservoir level falls below this limit, then no more than two turbines are allowed to be run at the same time. While the water level in the reservoir is low, water must be saved, and it would, therefore, be questionable to run the station at full load. But provision was made to care for the reopening of two turbines at any time after rejection of the load by two turbines, when the water in the reservoir was down to the lowest level (800ft).

It must be emphasised that in many hydraulic systems the surge oscillations may dampen out very slowly (Jaeger, 1949a). This is particularly so if the pressure tunnel is short, its diameter large, and its walls smooth. Surges may continue oscillating for hours.

If the period of the surge is comparable with the time required to synchronise a turbine, the final surge, after all the turbines have been put into operation one after the other, may not be very much less than if all the turbines had opened suddenly together.

This persistence of the surges over a long period of time has to be taken into account, especially when power stations are equipped with one or two turbines only.

It has been shown that there are a number of instances where surges produced by successive load changes can interfere and accumulate dangerously. Examples from actual practice have been mentioned, and a variety of influencing factors—reservoir levels, number of turbines, length of pressure tunnel, friction losses, &c.—has been enumerated.

The possibility, pointed out by Scimemi and Ghetti (1951), of selecting different "statism"‡ for the different power stations, thus putting all the weight of this load on one or two specially selected control stations, is of little help in some of the instances discussed in this paper. There is always the possibility of some stations being isolated accidentally or having to be isolated so as to localise a disturbance and avoid its spreading to other parts of the grid. Any large power station, even if not designed specifically to be a control station, may suddenly have to face the load variations of a whole grid.

This survey would be incomplete if mention were not made of another tendency. The French electricity network is characterised by its wide extent and numerous interconnections. The big industrial centres—Paris, the north of France, and the east—are fed directly by large steam generating stations which are located in the vicinity, and the total output of which covers about half the yearly demand of the French grid.

The large hydro-electric power stations, widely linked with each other and with the thermal stations, feed long transmission lines leading to Paris and the industrial centres. The load variations on the hydro-electric power system have rarely, in recent years, put a dangerous strain on any individual station. It has, therefore, been decided by Electricité de France that surge tanks shall, in future, be designed for throwing off full load, the negative surges thus produced being analysed as well as the preceding positive surges. It will be assumed that any negative surge produced by taking on load will have to be limited to a reasonable amount consistent with the case of "full load off," thus avoiding any considerable additional expense. The problem is, therefore, reversed, the need for greatest economy being put first and the safety of any new individual station being based on the extensive ramifications of a very large network. The rules of Electricité de France leave the matter open, however, by specifying that any new station shall be assessed on its own merits, while taking all the circumstances into account. Very important stations will still be designed on assumptions similar to those advocated by the Italian specialists.

Readers may very well reach the same conclusions, namely, that any new scheme shall be considered in relation to its circumstances, and that the appropriate loading shall be decided only after careful study of all aspects of the regulation problem.

‡ The curve of "statism" gives the steady speed w_s as a function of the load N.

Special Problems of Surge Stability

The question of surge stability has already been dealt with summarily on the lines of the theory of Thoma§ and it has been pointed out that several restrictive assumptions have been made explicitly or implicitly in the mathematical treatment by Thoma (1910).

The surges are supposed to be very small, all terms superior to the second order having been neglected; furthermore, the governor is assumed to maintain the output N rigidly at a constant value. The station efficiency is assumed to be constant. Finally, the station is supposed to be running alone on the grid with no possible interference from other stations. In practice, it may be that none of these assumptions will be correct, and further investigations may become necessary to ascertain how surge tanks behave under conditions where this is so, and to establish why they do sometimes behave differently from the manner forecast by the theory of Thoma. The whole problem requires more comprehensive treatment.

A much disputed point is the so-called factor of safety, $n=F/F_{Th}$, to be introduced into the condition of Thoma.‖ If the area of the surge tank were equal to the area of Thoma, then small oscillations would last indefinitely, and a certain factor of safety n must be introduced so that, if

$$F=nF_{Th}(\text{with } n>1)$$

the surges decrease, the primary surge being followed by others of decreasing magnitude.

It has been pointed out already that the decrement $\Delta=x_i+_1/x_i$ can be calculated or measured, and that it yields information which is more valuable than any discussion of the factor n.

Effect of Large Oscillations.—Some efforts were made to extend the theory of Thoma to the case of large oscillations. Let the small oscillations be written in the form $\frac{d^2x}{dt^2}+2a\frac{dx}{dt}+bx=0$ (where $x=Pw_0^2+z$ and a and b are constant if the oscillations are supposed to be infinitely small), which can be multiplied by $(dx/dt)dt$ and integrated.

The left-hand number of this equation then represents the sum of the kinetic energy and of the potential energy of the oscillations between the time limits $t=0$ and t. If a and b are positive, then the oscillations are stable and the sum of the two energies is always negative.

It can be shown that this is true also for large oscillations and if the area of Thoma, F_{Th}, is increased by the factor

$$\left(1+0{\cdot}482\frac{Z_e}{H-Pw_0^2}\right)$$

large oscillations will also be stable. The formula agrees with the results of detailed calculations point by point.

Measurements carried out by Ghetti (1951) on existing surge tanks indicate that the damping of large oscillations is in some instances more efficient than is indicated by this formula. The obvious explanation is that large oscillations introduce additional friction losses when the water is diverted from the pressure tunnel into the surge tank, which is most frequently at right angles to the former. These additional friction losses depend on the ratio of vF/wf. Treatment of the problem is difficult for cases other than that of total closing, when $wf=vF$, which is of little interest for stability studies. In the more general case, the treatment must follow the lines of the theory developed by Escande (1952) for the surge tank with restricted orifice. According to circumstances, the damping effect of losses due to the additional bend may or may not prevail against the additional instability shown by the formula.

Surge Tank with Restricted Orifice.—Additional losses occur (Escande, 1952) when the water passes through the restricted orifice, in both the upward and the downward directions, so that the stability conditions in a throttled surge tank cannot be worse than in a simple tank. They must be better. Let it be assumed, therefore, that the tank is slightly unstable and that the condition of Thoma for small oscillations is not satisfied. In relative values the condition of Thoma is equivalent to :—

$$2p_0h_0>1$$

where $p_0=Pw^2/Z_*$ and $h_0=H_0/Z_*$ (H_0 being the net head).

The conclusion of a study by Escande (1952) is that when $2p_0h_0<1$ (the condition of Thoma not being observed) there is no final damping of the oscillations, but a state of equilibrium is created with stable oscillations of limited constant but by no means negligible amplitude x_{max}, which depends on the three factors h_0, p_0, and r_0, where r_0=relative value of the throttle losses.

The governor must be adapted to deal with this continuous variation of the head without creating unsteadiness in the electrical distribution system. Furthermore, there is an increased danger of surges becoming superimposed both in the positive and negative directions on any occasion of load change. There is a strong argument in support of observing the condition of Thoma for a throttled surge tank also, because the greater oscillations x_{max} may prove to be objectionable.

Stability of Differential Surge Tanks.—Let r_0v^2 be the relative value of the orifice losses for full discharge. The surge in a differential surge tank will certainly depend upon F_1, F_2, r_0, and p.

No theory of the stability conditions for differential surge tanks has yet been established, but it can be shown that the theory of the ordinary throttled tank provides the key to part of the theory for differential surge tanks (Jaeger, 1952).

In some instances, where the orifice at the base of the inner riser is large (r_0 small), the differential surge tank behaves as an ordinary throttled surge tank. There is no spilling, or only a negligible quantity, over the inner riser, the maximum surge being identical with the surge in a throttled surge tank. In such a case, the condition of Thoma refers to the area of the outer reservoir, F_1, and when this condition is not satisfied for small oscillations, a state of equilibrium may be reached with large oscillations occurring similarly to those in throttled surge tanks with too small an area ($F<F_{Th}$). The conditions for the downward surge should be identical with those for the upward surge, from which the minimum height of the tank may be calculated. Instances may occur (when $2p_0h_0<1$) where this total height becomes greater than the first surges for closing and for opening added together.

When the area of the restricted orifice is small and the throttling of the water passing into the outer chamber is effective (r_0 great), the water will reach the top of the inner riser and will spill over during the first period of the rising surge. The limit of the upward surge is then virtually equal to the height of the inner riser. A similar limit does not, however, exist for the downward surge. The diameter, D_2, of the inner riser can no longer be neglected when the damping of the oscillations is being considered, and there is an obvious danger of unstable oscillations in the downward direction.

Full stability will certainly be obtained when the area F_2 of the inner riser satisfies the condition of Thoma. Differential surge tanks connected to high-head plants are likely to fulfil this condition and to be stable. Others, especially those connected to low-head plants, may be unstable.

Differential surge tanks, with small orifices, when connected to low-head power stations, must be specially checked in regard to their stability. This can be done by a step-by-step calculation, or, alternatively, with a model to scale.

Effect of the Velocity Head : Venturi Effect.—When the surge tank is on the upstream side of the turbine, the theory shows (Calame and Gaden, 1926 and 1927; Jaeger, 1949*a*) that the velocity head $w_0^2/2g$ can be added to the friction losses, and the quantity $P'w_0^2=\frac{w_0^2}{2g}+Pw_0^2=\left(\frac{1}{2g}+P\right)w_0^2$ will appear in the denominator in the formula of

§ This portion of the paper is omitted.

‖ $F\geq F_{Th}=\frac{w_0^2}{2g}\frac{Lf}{Pw_0^2H_0}$

Thoma instead of Pw_0^2. Furthermore, this $w_0^2/2g$ is not lost for the net head, which should include this amount.

When the head is low and the tunnel short, this theoretical effect of $w_0^2/2g$ may be very considerable, and it has been proposed to increase the damping by introducing a Venturi effect in the form of converging cone and an expanding taper pipe at the bottom of the surge tank, as illustrated in Fig. 2, where this Venturi is shown in association with a throttled surge tank.

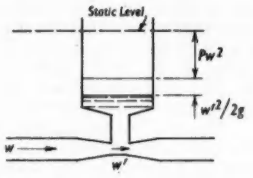


Fig. 2—Surge Tank with Restricted Orifice and Venturi Effect

The efficiency of such an arrangement can be tested on a model. On the other hand, experience with models shows that, when the water in the tank is low, its surface may be quite unsteady with unexpected passages from the piezometric level to the energy level. These are indications that perhaps only part of the $w_0^2/2g$ is effective in damping the surges.

Conditions are less clear when the surge tank is on the downstream side of the turbines, the tail-race tunnel being under pressure and discharging into a river or lake of which it is thus a tributary. Hydraulic conditions at the junction of the tunnel and the river or lake have never been investigated, and the theory does not prove that the full value of $w_0^2/2g$ can then be used in the stability equations.

Effect of the Power Station Efficiency.—In all the previous calculations it has been assumed that the turbine efficiency η is constant. It is possible to show that the varying efficiency of the turbine has a powerful stabilising effect when $d\eta/dN>0$, but adds to the instability on those regions of the curve $\eta=\eta(N)$, where $d\eta/dN<0$.

A long pipeline has the same effect as a negative $d\eta/dN$ value and, therefore, increases the danger of instability. Both effects can be examined when analysing a stability curve by a step-by-step calculation.

Stability of Systems of Surge Tanks.—A system in which there is more than one surge shaft on a pressure tunnel, or in which several pressure tunnels run into the same main shaft, will be referred to as a "system of surge tanks." With the ever-increasing capacity of modern power stations, systems of surge tanks are being used more frequently. The case should also be noted where additional water is introduced into the hydraulic system by way of adits on shafts located between the main intake and the surge shaft or tank.

In some instances, the main surge tank has been split into two or more shafts for construction reasons. When modernising and enlarging an existing power station, the designer may have to develop a system of surge tanks by adding new shafts to the existing one. A new design which has sometimes been adopted in recent years consists of a reaction turbine with pressure tunnels on the upstream and the downstream side, each with its own surge tank.

The following rules summarise roughly the main results (obtained from the general theorem of Hurwitz on stable oscillations) when two surge tanks are connected to the same pressure tunnel on the upstream side of the turbine :—

If the surge shaft nearer the turbines satisfies the condition of Thoma ($F_2>F_{Th}$) the system will be stable, whatever the dimensions of the second surge tank.

If the nearer surge tank is smaller than the area indicated by Thoma, but larger than half this area ($\frac{1}{2}F_{Th}<F_2<F_{Th}$) then the sum of the areas of the two surge tanks (F_1+F_2) will have to be larger than F_{Th}. If the second surge tank is close to the nearer one, then a small margin of the total areas above F_{Th} may be sufficient to secure stability of the system. If the second surge tank is nearer the tunnel intake, then its area will have to be very considerable and the proper solution will be adherence to the rule of Thoma for the lower surge tank.

The rules giving the minimum permissible area of F_1 and F_2 as a function of their location are complicated.

When the turbine is a reaction wheel with surge tanks on both the upstream and the downstream sides, it does not seem possible to apply the general rule of Hurwitz. Studies yield a somewhat different theory with the result that, owing to mutual interference of the oscillations in the upstream and the downstream tanks, the limiting value given by Thoma has to be greatly exceeded (Jaeger, 1949*a*). These results have been checked by direct calculations.

When examining modern designs for systems of surge tanks, it will be found that the simple shafts on which the theorising is based are actually replaced by throttled or differential surge shafts. In some other instances, the shaft is provided with a spillway. Instability can also occur with arrangements similar to Fig. 3,

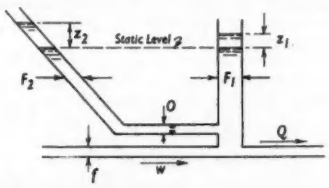


Fig. 3—Secondary Oscillations in System of Surge Tanks Damped by Restricted Orifice O

where secondary oscillations between the two surge shafts may arise. These can be kept within reasonable limits by the introduction of a restricted orifice at some suitable point.

There is no general analytical method for dealing with the stability of such complex systems. Direct calculation step-by-step, or studies by means of a proper model must be carried out.

Effect of Interconnection of Power Stations.—The theory of Thoma assumes that the station is isolated and working alone on the electric network. Let it now be assumed that the station is connected to a larger grid with a load N_s, N being the load of the particular station to be considered. Let

$$k=\frac{dN}{dN_s}\simeq\frac{N}{N_s}$$

all the stations having the same statism.

It has been proved several times (Calame and Gaden, 1927; Evangelisti, 1947*a*; Jaeger, 1949*a*) that in such circumstances the formula of Thoma becomes :

$$F_{Th}=\frac{w_0^2}{2g}\frac{Lf}{H_0Pw_0^2}\{1-\tfrac{1}{2}(1-k)\}$$

The value F_{Th} becomes zero if $k=\frac{1}{2}$. Thus, when a station supplies less than a third of the load of the system, its surge chamber is always stable. A direct consequence of this fact is that, when any station is to be tested for its surge stability, it must be isolated from other stations and loaded from a limited grid or by a water resistance.

In developed and industrialised countries surge instability will appear only if a station is accidentally disconnected from the larger grid and forced to work in isolation. When hydro-electric power stations are liable to work alone or when, owing to long connecting lines, stations may be isolated accidentally, the condition of Thoma must be observed at all costs.

Interaction of Surges, Water Hammer and Turbine Governing.—When introducing the theory of Thoma, it was made quite clear that the governor was assumed to react to an abrupt change of the load which was then to remain steady, with no further reaction of the governor. The load varies from

$$N^* \text{ to } N_0=N^*+\Delta N$$

On the other hand, when analysing the mechanism of a water turbine governor, it is assumed that it reacts immediately to any change of the load, and will also be able to deal with the rapid pressure changes occurring in the pipe (water hammer). These may violently oppose the regulating action of the governor and may even make such action impossible. In some instances, relief valves are fitted to the turbines to decrease the effects of water hammer and facilitate regulation.

In this classical treatment of the action of the governor it is assumed that the period of surge oscillations is long and does not interfere with the turbine regulation. For many years the two problems of turbine governing and surge stability were treated independently.

Mention has already been made of the unsteady oscillations in the surge shaft of the Heimbach power station, and of how this is always quoted as a classic example to prove the correctness of the theory of Thoma.

It will now be compared with the more recent tests which have been carried out on a large scale by Scimemi (1947) and Ghetti (1947*a*, 1951) at several power stations (mainly belonging to the Societa Adriatica di Elettricita), and which tend to show that the limit of surge stability is not as clear cut as is indicated by the formula of Thoma.

TABLE I—*Tests at Several Power Stations*

Name of power station	Date of test	F, square metres	F_{Th}, square metres	$n=\frac{F}{F_{Th}}$	Other data
Pelos : (Damped oscillations lasting about ½ to 1 hour)	March 8, 1947	11·4	16	0·71	H =130m Tunnel length L=5,151m Tunnel diameter 2·9m to 3·6m Losses $Pw^2=1\cdot3w^2$ Unloading from 10,600kW to 6,600kW
Fadalto : (Oscillations at the limit of stability)	March 15, 1947 May 25, 1947	31·7	65	0·49	H =110m to 90m L =2,515m D =5·8m Cross-sectional area of tunnel f=31·7 square metres Losses $Pw^2=0\cdot66w^2$ Unloading from 28,000kW to 18,000kW
Partidor : (First series of tests—damped oscillations lasting 2½ hours) (Second series of tests—stable and unstable oscillations were produced)	April 14, 1947 April 27 to 30, 1950	39·6	60	0·66	H =28·6m to 19m L =914m D =3·05m Unloading from 500kW to 350kW
Caerano : (Oscillations dangerously unstable)	June 3, 1947	12·56	85	0·16	H =17·0m to 16m L =1,784m D =2·80m f =6·16 square metres Losses $Pw^2=0\cdot38w^2$ Constant load of 690kW Constant load of 720kW Load variations between 900kW and 1,070kW
Heimbach : (Unsteady oscillations)	1904	4·9	5·35	0·92	H =70m to 110m Q_0 =20 cubic metres per second L =2,700m f =6·5 square metres

Table I reproduces data collected from these tests.

The first series of tests (1947) shows that several surge tanks were found to be stable for values of $n<1$ (in this series, values of $n=0\cdot5$ to $0\cdot7$ were observed at the limit). But some of the damped oscillations lasted very long. They seem to stay longer with a short tunnel (Jaeger, 1949*a*).

The second series of tests on the Partidor power station in 1950 (Table I) were carried out by

Scimemi and Ghetti and commented on by Ghetti (1951). Considerable hydraulic surges (about 20 per cent of the head H) were observed both of the damped and of the undamped types, and they were related to frequency variations. It was possible to have stable and unstable frequencies for this same hydraulic system, and for the same opening of the turbine (therefore for identical hydraulic conditions) simply by changing the sensitiveness of the governor. The conclusions of Ghetti are that the favourable results of the first series of tests were due partly to the type of governor used in the stations, and that changes in the governor could modify the results of the tests. Evangelisti (1950), when scrutinising the first series of tests by Scimemi, came to similar conclusions. He developed a more detailed theory of surge stability assuming that the governor also reacts on the surges within certain limits.

This new, rather involved, theory finally yields an equation of the type

$$C_0r^3+C_1r+C_2=0$$

where C_1 contains terms depending on the governor (r=root of the accompanying characteristic equation).

Evangelisti and Ghetti studied the Heimbach, the Pelos and the Caerano power stations on the basis of the full value to be given for C_1. It was found that in all three instances the two first terms of C_1 were negative, but in the case of Pelos the corrective terms concerning the governor were positive and would quite likely overbalance the negative terms of C_1. This was not so for the two other power stations. The governor of Partidor had also to be modified by Ghetti. Inspection of the curves published by the Italian specialists (Evangelisti, Ghetti and Scimemi) proves that a limited amount of surge stability can be achieved through the action of the governors.

For the time being only provisional conclusions are possible on this difficult matter of surge tank stability.

The Italian specialists (Evangelisti, Ghetti and Scimemi) essayed to prove by means of mathematical analysis and field tests the importance of proper turbine governing for keeping down the surge oscillations. Despite the limitations theirs is an indisputable achievement. Notwithstanding those efforts, however, some very important points have not been cleared up. For further discussion of the Italian results the damping effect of throttling at the base of the surge tank—and the mere changes of direction of the flow are equivalent to a partial throttling—should also be considered, as it has been made clear that this provides an additional damping effect. A second comment questions the finality of the Italian tests. Several authors have insisted on the stabilising effect of the η value (η=efficiency factor of the turbine and pressure pipe) in the domain where $d\eta/dN>0$. Although this point is not mentioned in the discussion of the Italian tests, it is presumed that most of them were carried out for values of $d\eta/dN>0$, when it was to be expected that the damping effect therefrom would be considerable.

It must be stressed that all these factors—additional surge stability from governor action, additional throttling losses, efficiency variation—may add their stabilising effects as they probably did for the tests in Italy, but in certain circumstances they may vanish, or even work in the opposite direction (if $d\eta/dN<0$).

It is of great value to know that there is a certain amount of stability margin in the calculations, but for the time being no precise figures can be assessed.

In spite of being disputed, this simple formula of Thoma remains a most important criterion for designers. When allowance is made for all latter-day results, confidence in this formula is not greatly impaired. It does not matter so much to know whether the mathematical instability of the surges begins for an F value slightly smaller than or just equal to F_{Th}. It is known definitely that for $F=F_{Th}$ the surge amplitude may reach disquieting values. The designer should be more interested in the decrement $\Delta=x_{t+1}/x_t$ of these surges (Jaeger, 1949*a*). A theoretical formula which is corroborated by many direct step-by-step calculations (graphical or analytical), as well as by site measurements, shows that Δ depends primarily on the tunnel characteristics—length, cross-sectional area, roughness of the walls, and total friction losses. For surge tank design the right estimate of Δ is of great importance. Furthermore, there is definitely a link between the problem of surge stability defined by Δ and the assumptions concerning the dangerous loading conditions (discussed above under Loading Conditions to be Adopted), which also depend on Δ. Finally, the correlations between the decrement Δ of the surge oscillations and the frequency variations on the electrical network should be studied closely.

Water Hammer and Surge Tank Design

Hitherto it has been assumed that the surge tank reflects downwards all the pressure waves travelling from the turbine along the pipeline in the upstream direction. Water hammer has already been considered for its reactions on turbine governing. It will now have to be considered in regard to pressure distribution along the whole hydraulic system, comprising pipeline (or a system of pipelines or penstocks), surge tank, and pressure tunnel.

It is possible to generalise the water hammer theory of Allievi (1913) for the case where a surge tank is designed at the upstream or at the downstream end of the pipeline. It can be shown (Jaeger, 1933) that, for a single pressure pipeline the water hammer depends on two relative values $\rho=av_0/(2gH_0)$ and $\theta=\tau/(2L/a)$ only (where v_0 =velocity in the pipe and τ=closing time of the gates). The hydraulic system, consisting of pressure tunnel, surge tank, and pressure pipeline, can be represented by a system of three pipes (1, 2, and 3) interconnected at point A (Fig. 4).

Any wave travelling upwards in the pipe 3 (pipeline) when arriving at point A will be divided. A part of the wave travels up pipe 2

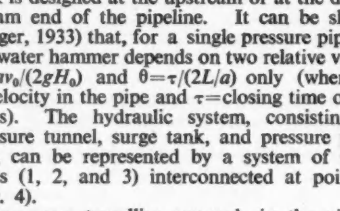


Fig. 4—Water Hammer in a Pressure Pipe System Including a Surge Tank

(surge tank), another part penetrates into pipe 1 (pressure tunnel), and a third is reflected towards the pipeline in the downward direction.

Starting from these fundamental statements, it is possible to calculate the pressure distribution in the whole system. The problem can be solved by the graphical method of Schnyder-Bergeron (Bergeron, 1935), but the analytical method shows some superiority in giving more general and quicker results (Jaeger, 1933, 1949*a*).

The practical conclusions to be drawn from detailed calculations is that in most instances the surge tank conveniently protects the pressure tunnel against positive and negative pressure waves, the percentage of pressure penetrating into the tunnel not being dangerous. There are few exceptions. Some will occur when the surge tank is a long inclined pipe with a diameter comparable to the penstock or tunnel diameter. In such instances an appreciable amount of pressure will penetrate the tunnel (or pressure pipe). Negative pressure waves will be more difficult to deal with and may require that the pressure tunnel and the connection to the surge tank should be moved to a lower level.

It is essential to check the dynamic pressure drop at the valve house, downstream of the surge tank. It is a common error of design to locate the valve house at too high a level, where surges and water hammer combined may produce pressures below atmospheric. Relocation of the valve house may entail an increase in the gradient of the penstock between surge tank and valve house.

The problem of water hammer wave reflection requires special care when the surge tank is of the restricted orifice (throttled) type. A restricted orifice, like many diaphragms, produces concentrated localised losses, to some extent hiding the wave transmission. Formulæ for restricted orifice surge tanks were published by Jaeger (1933). A recent Italian paper (Benini, 1950) arrives at the same formulæ, which compared well with the results of model tests. As the pressure rise below the restricted orifice is very rapid, it is also being transmitted without reduction upstream and penetrating deeply into the pressure tunnel.

With the increasing popularity of throttled surge tanks these aspects merit full attention.

It would be a dangerous illusion to think that a surge tank will stop any type of pressure wave. It is an established fact that pressure tunnels have been severely damaged by water hammer in spite of ample protection by surge tanks. One type of wave may pass a surge tank and penetrate into the tunnel (Jaeger, 1948, 1949*a*) : there are the upper harmonics, generated by resonance in the pressure system. Resonance of this type may be promoted by a governor, but resonance may also occur with no fault from the governor whatsoever.

Surge Tanks Connected to Feeder Canals

Before 1910 many power stations were designed without proper surge tanks, the pressure tunnel being replaced by an open canal or a free-flow tunnel. This layout has never completely disappeared, and very recent designs show the same features. In some instances the canal is directly connected to the turbine intake (Fig. 5*a*), while in others the canal discharges

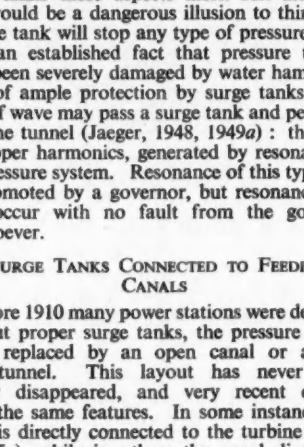


Fig. 5—Feeding of Power Stations by Head Race Canals : Formation of Translating Waves

into a surge tank (Fig. 5*b*). Turbine regulation will produce translatory waves in the canal, and in some instances the regulation may have a character of instability which compares to some extent with the instability of surges. An example is Oelberg power station, Switzerland (Cuénod and Gardel, 1952).

This instability may become particularly disturbing if a number of power stations of similar design are working in series along the same main canal, and even more so, if the canal is used for continuous irrigation. It will then be found that special attention has to be given to some alternative means of regulating water discharge and turbine output. The problem has never been dealt with completely and undoubtedly it deserves close attention. It is likely that the surge tanks, if there are any, stabilise the system.

Special mention needs to be made of a particular type of underground station, where a downstream tunnel discharges water with a free level, as long as the discharge is steady. For large variations of load the tunnel will be put under pressure, the water rising in a chamber which has been called a "partial working" surge chamber. Experience gained at Wettingen power station, Switzerland, has proved such a system to be stable.

Final Remarks

A fascinating aspect of the design of hydro-electric power plant is the complexity and the multiple interactions of the components involved. The surge tank problem is quite typical in this respect. At the starting point of this analysis are found some simple physical principles and very simple differential equations. The methods of integration are easy, but suddenly problems arise. It is discovered that the surge tank pulsates ; it reacts to the turbine governor, and it reacts to the water hammer.

It is necessary to insist on the complexity of the reactions of the surge tank. With the growing dimensions of power stations, incorporating more and more powerful generating sets with even

greater discharges, the design of surge tanks becomes still more complicated. Systems of surge tanks replace the single surge tank. If the station is of the underground type instead of the conventional surface power-house, the problems to be solved may be the more difficult because of conditions peculiar to such underground stations.

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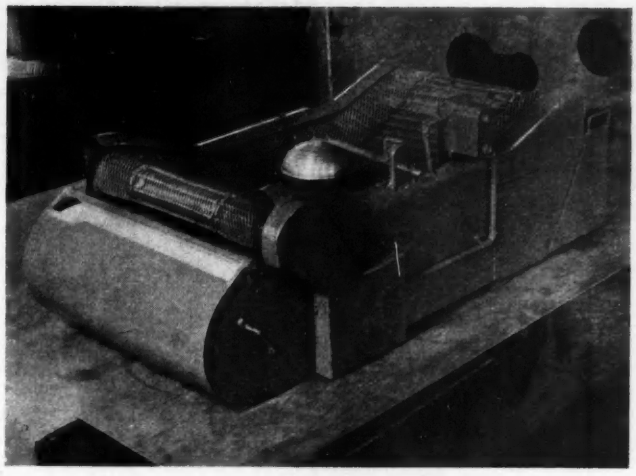
Filter for Removing Solids from Liquids

WE illustrate herewith an industrial filter, which is now being distributed by Newall Group Sales, Ltd., Old Fletton, Peterborough. This unit is designed to remove solids suspended in liquids, such as machining coolants, and is of continuous self-cleaning construction. In it liquids flow by gravity through a filtering medium, leaving the solids on its surface to be discharged in a relatively dry state into an outside container.

The bonded fibre fabric used for filtering is supplied in a roll, and a length of it rests on and conforms to the shape of the endless woven wire conveyor of open construction, to be seen in the illustration. The sloping sides of this conveyor form a shallow depression into which the dirty liquid pours and forms a pool on the filter fabric. The liquid filters through the fabric, leaving its suspended solids on the surface.

After a period of working the solids build up on the filter fabric to a depth which is sufficient to prevent the liquid gravitating through, and the level of liquid in the pool rises. A float supported by an arm from the side of the filter casing is suspended over the pool and when this



Continuous Self-Cleaning Gravity Filter

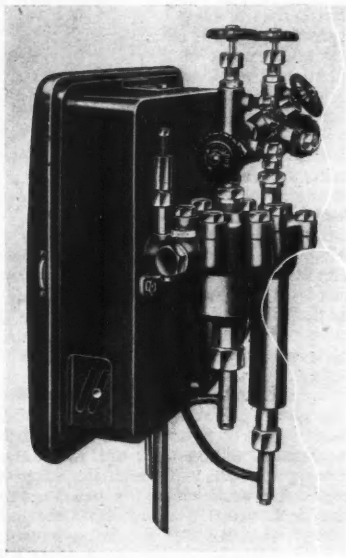
float is lifted by the rising level of the liquid its arm contacts a power switch. At a predetermined level the switch starts a small motor, which drives the conveyor. As the conveyor moves it carries the fabric supporting the filtered solids forwards and brings a further length of clean fabric into the filtering position. The float then drops with the falling level of the liquid as it gravitates through the clean fabric. When the float drops the supply of current to the conveyor motor is switched off until the need for clean filter material again causes the liquid level to rise, when the cycle is repeated.

The maker of this "Filtrall" filter states that it is being used for filtering of oils used in running-in engines, test bed oil for hydraulically operated parts, quenching oils, paint spray booth water, cooling tower water and air conditioning plant wash water. It is a completely self-contained unit and can be readily adapted for use with existing plant layouts.

Flow Meter

A DESIGN of flow meter now being produced by George Kent, Ltd., of Luton, represents the first step in a new policy of standardisation which has been introduced by the firm. This standardisation will cover the "presentation" mechanism—that is, the case and front mechanism including the recording, indicating and automatic control systems. The new range of meters is to be known as the firm's "Commander" class and the "KU" meter just introduced is the first of its kind. The maker points out that under the new standardisation policy users will be able to fit additional presentation features to a meter, or change parts between one meter and another, whilst the number of spare parts it is necessary to stock can be kept to a minimum. The "pre-calibration" of relevant parts increases flexibility by allowing a user to assemble a variety of instruments from standard units, should he so desire, as well as to alter ranges easily.

The accompanying illustrations of the new "KU" meter show its front and back. This meter is available for the recording, indicating, integration and automatic control of the flow of oil, water, air, gas, steam and most industrial liquids. It works in conjunction with a Venturi tube, Dall tube or orifice in the fluid pipeline. The meter has forged steel interchangeable mercury chambers, designed to receive maximum differential pressures of 25in, 50in, 100in, 200in, 400in or 600in of water. The 25in head chamber withstands a test pressure of 500 lb per square inch, and all other chambers 4000 lb per square inch, the maximum working pressures being 250 lb and 2000 lb per square inch respectively. The nuts of special joints used on the chambers can be tightened with the fingers to hold the full test pressure. A new design of float in the downstream chamber rises for an increase in differential pressure. The extension of the U-tube is thus downwards, and the easily separable control head is a standard unit. Only a new upstream mercury chamber and U-tube are required for a range change, which can be made on site. An adjustable throttle valve in the downstream leg of the U-tube damps out

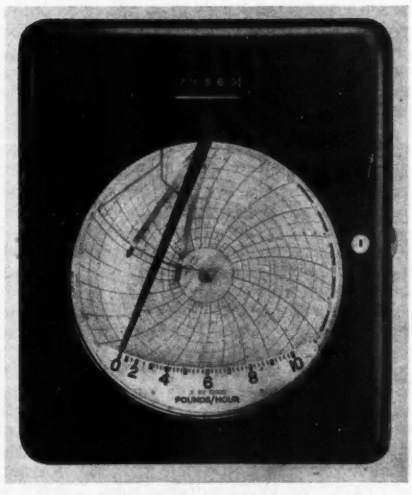


Back of Meter Showing Mercury Chambers and Control Head

the effect of a pulsating flow characteristic, and streamlined overload valves provide a safeguard against loss of mercury on excess or reverse loads. The control head incorporates two mild steel forgings specially designed to reduce the number of joints to a minimum.

The movement of the float is transmitted to the presentation mechanism through a grease-packed gland, designed to reduce friction to a minimum. A jewel thrust bearing is provided for the gland spindle.

The presentation mechanism can accommodate up to two pens and a pointer, as illustrated, the second pen being used for pressure measurement from a pre-calibrated Bourdon tube unit mounted



Front of Flow Meter

in the case. Over-range protection is provided for the pens in both directions of movement. The pointer rotates on the same axis as the pens and it indicates on a crescent-shaped, 8in long scale. The pen is an integral part of the pen arm, which slides easily in or out of an aperture on the pen spindle arm automatically locating itself. A light and finely tempered pen arm maintains the correct pressure of the pen on the chart without being subject to any torsional movement due to frictional loads. When the meter door is opened, the pens and pointer are automatically lifted clear of the chart, if desired, making chart changing an easy matter. The charts comply with British Standard recommendations and the printing and layout have been arranged so that all relevant figuring is the right way up when the chart is viewed, the flow variable increasing vertically and the time figures increasing to the right. The charts can be of decimal or direct reading design and for daily or weekly rotation, using a mechanical or electrical clock. A quick-release chart hub locates the chart on to the clock, or releases it, as the result of a push or pull action on the hub, and no screwing or unscrewing is necessary.

The integrator can be electrically or mechanically driven and is a separate pre-calibrated unit. The electrical integrator has a large five-figure cyclometer counter, a range of up to 10 : 1, a minimum step error, and is unaffected by vibration. The mechanical integrator uses a direct linkage to operate a tractor wheel frame instead of the conventional cam, an arrangement claimed to reduce greatly the power required.

The case and door of the meter are aluminium die castings, of British Standard dimensions, the case acting only as an envelope for the mechanism, which is mounted on a separate plate. With the door open, the mechanism is masked by two easily removable plates, the lower one of which forms the platform for the chart and carries the meter data plate.

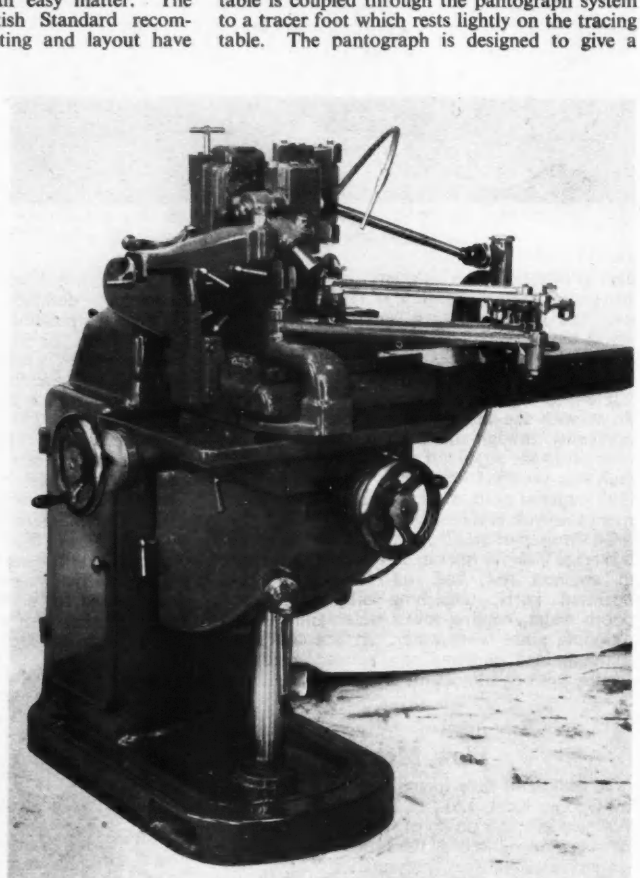
Unified screw threads are used throughout in the instrument. The mounting frame embodies a fitting for wall or post mounting, as an alternative to panel mounting. For wall mounting, the instrument fits on a trumpet-shaped casting bolted to the wall, whilst for panel mounting the British Standard "cut-out" is a rectangular hole only, without holes for fixing screws, the meter being held rigidly in place by three adjustable wedge clamps.

Profile Grinding Machine

A PROFILE grinding machine now being made by Maskinaktiebolaget Karlebo, Kungsgatan 33, Stockholm, Sweden, is illustrated herewith. This machine is used with a profile template of the workpiece, five times larger than the required finished size, which is mounted on a tracing table on the right-hand side of the machine. The workpiece is supported on a floating table which is actuated through a pantograph system as a tracer is moved round the template contour. The grinding wheel reciprocates in a vertical direction as the workpiece moves across it to form the required profile.

The machine has a rigid cast iron box-frame base within which are arranged the ¾ h.p. driving motor, electrical control gear, coolant tank and coolant pump. The main longitudinal and transverse slides of the machine are mounted on a heavy knee, giving a vertical adjustment of 9in. Both of these slides are handwheel operated with reference to vernier micrometer scales, and they give a length of longitudinal adjustment of 9¼in and a transverse adjustment of 4in.

The floating table, mounted on the main table of the machine, is carried on two sets of slides arranged at right angles and supported on balls to give a smooth uniform motion. The floating table is coupled through the pantograph system to a tracer foot which rests lightly on the tracing table. The pantograph is designed to give a 5 to 1 reduction between the tracer and the floating table and by direct reproduction profiles up to 3¾in long by 1¼in deep can be ground on workpieces. By indirect methods profiles up to 12in long can be reproduced.



Profile Grinding Machine

The floating table has tee slots in its upper face for the clamping of large workpieces or a circular grinding attachment, or a feed slide. The template table is attached to the end of the main longitudinal slide of the machine and has tee slots and clamps for rigidly holding the plates.

The grinding wheel spindle is driven at 3600 r.p.m. and is mounted on a slide assembly on the machine column. This slide assembly can be inclined to impart face angles on workpieces from plus 45 deg. to minus 5 deg., or side clearance angles up to 5 deg. each way. During the grinding operation the spindle slide is reciprocated by a crank which gives it a stroke of about 1½in, and 100 strokes a minute.

The face of the tracer mounted in the foot of the pantograph is shaped in accordance with the profile being reproduced, and a series of tracers can be used in forming complicated workpieces. If required, a special diamond wheel forming attachment can be fitted on the machine to impart a profile on the wheel corresponding to the tracer face with a 1 to 5 ratio. This attachment can be seen in position in the photograph we reproduce. For grinding circular form tools, milling cutters, &c., a circular grinding attachment can be fitted to the floating table and this attachment has its spindle driven from a power take-off at the side of the machine column.

African Engineering News

(By Our South African Correspondent)

Hydro-Electric Power Scheme on the Congo

Brazzaville, the federal capital of French Equatorial Africa, is to have a hydro-electric installation about 6 miles away on the Djoué River, a tributary of the Congo. The contract for the work was given to the company, Energie Electrique d'A.E.F., in 1950. The Djoué, which has a minimum rate of flow of over 3000 cusecs, winds considerably in its last few miles, and one of its bends comes within 1000 yards of the Congo. At this point the difference in the level of the two rivers is about 80ft, thus giving the head utilised by the new power scheme.

The power station will have an installed capacity of 15MW in two turbo-alternator sets, which will be increased to 30MW in the second stage of the scheme. A dam, 775ft long and 26ft high, will impound the Djoué and create a reservoir of about 275 million cubic feet. This dam will be equipped with two sluice gates 19ft 6in by 9ft 6in in size, which can release a maximum of about 7500 cusecs. The capacity of the intake and tunnel to the power station is 2000 cusecs. The horse-shoe-shaped tunnel is about 16ft in diameter and half-a-mile long and is lined with concrete. Two underground penstocks each lead to a Kaplan turbine developing 10,500 h.p., under a head varying between 68ft and 87ft. In the second stage a second tunnel is envisaged. The overall measurements of the power station are 124ft by 80ft wide for the first stage. Lastly, a tail race channel some 700ft long leads to an arm of the Congo. An outside transformer station is at present envisaged, with one 30kV line leading to Brazzaville and one for the Belgian Congo. All told, the progress of the work is being kept to schedule and the inauguration of the second turbo-alternator set should take place next month

Free State Gold Production

The rapidly increasing output of gold from South Africa's comparatively young Free State goldfields is reflected in production figures recently issued by the Chamber of Mines. During August, three new mines in the Free State started production and the Province's total output during the month was 43,525 ounces—an increase of 17,196 ounces compared with June. The production value increased by £212,079 to £537,352 in July. Since the first two Free State mines—St. Helena and Welkom—started work, production in the Province has risen steadily. With five producers now operating after Freddies North and South and Western Holdings entered the production schedule last month, there should be a further steady rise. There will eventually be thirteen gold mines in the Free State. The remaining eight should come into production within the next three years. The Union's total gold output during July was 1,030,089 ounces, valued at £12,717,307, which is an increase of 60,268 ounces, worth £735,976. This includes the production of all the Transvaal mines.

Synthetic Oil Project

The originally-planned output of "Sasol," the South African Fischer-Tropsch plant for the production of oil from coal, will eventually be more than doubled. The undertaking was first planned to produce 30,000,000 gallons of oil products a year, but plans for the project have now been made to enable it to produce 70,000,000 gallons a year. It is hoped that Sasol's power station will be completed within a year and provided there is no further delay in the delivery of the required equipment, it should not take longer than eighteen months before production of petrol is started.

CHROME-LINED CYLINDER BORES.—A booklet has been prepared by Commer Cars, Ltd., Luton, which refers to the process adopted on its petrol engines for lining the cylinder bores with porous chrome. The advantages claimed for this treatment and some commercial engine life statistics are included.

Industrial and Labour Notes

Engineering Wages

On Thursday of last week there was another meeting between representatives of the Engineering and Allied Employers' National Federation and the Confederation of Shipbuilding and Engineering Unions concerning the claim made by the unions for a 15 per cent increase in the wages of adult male workers in the engineering industry. Early in October the Employers' Federation rejected the claim, but, subsequently, further representations were made by the union confederation, following a meeting of the executive of the Confederation of Shipbuilding and Engineering Unions.

At last Thursday's meeting, the employers' representatives again rejected the demand. It was pointed out that earnings in the engineering industry, since the last wage increase was made, had more than kept pace with the rise in living costs, and that any wage increase now would inevitably lead to increased prices of engineering products. Such a step, it was emphasised, was not possible in view of the strong and growing competition, especially in overseas markets. After hearing the rejection, the president of the Confederation of Shipbuilding and Engineering Unions, Mr. H. G. Brotherton, stated that a special meeting of the executives of all the affiliated unions would be held on November 19th to consider the situation.

Reference to the wage claim was made on Monday last by Mr. Jack Tanner, chairman of the Trades Union Congress and president of the Amalgamated Engineering Union. At a meeting in Manchester, Mr. Tanner said that irrespective of the outcome of the negotiations, it was essential that there should be increased productivity. That was a matter which affected all workers, as the country depended on exports, and these, Mr. Tanner observed, came directly or indirectly from the engineering industry.

Iron and Steel Production

British steel production established a new record during October. The output of ingots and castings averaged 355,000 tons a week, which means that production was running at an annual rate of 18,462,000 tons, compared with a rate of 17,044,000 tons in October last year. The British Iron and Steel Federation says that during the first ten months of this year steel production averaged 336,300 tons a week, and was thus at an annual rate of 17,489,000 tons, compared with an annual rate of 15,917,000 tons over the first ten months of 1952.

Pig iron output was also at a record level in October. The average weekly production was 221,500 tons, which represents an annual rate of 11,519,000 tons. During the first ten months of the present year, the annual production rate for pig iron has averaged 11,045,000 tons, compared with a rate of 10,482,000 tons in the corresponding period of 1952.

Apprenticeships in the Coal Mining Industry

The National Coal Board has announced the introduction of an apprenticeship scheme to provide the coal mining industry with trained mechanical and electrical engineering craftsmen. The scheme has been designed to provide a co-ordinated course of progressive practical training and technical education lasting five years. It has been agreed with the National Union of Mineworkers, the union being represented on the committees which will advise on the operation of the scheme in each of the Coal Board's areas, and which will interview candidates and recommend boys for apprenticeships.

No premium will be charged, and the apprentices are to receive wages at rates fixed by the joint national negotiating committee of the Coal Board and the union. Apprentices are to be allowed part-time day release from work, with pay, on one or two half-days a week, the Coal Board paying all fees for approved technical education, travelling expenses and lodging allowance where applicable. The training syllabuses have been drawn up in agreement with the appropriate professional bodies. These apprenticeships are open to boys already working in the coal mining industry and also to boys outside the industry. They should be under seventeen years of age, have a good standard of intelligence and educational attainment, be physically suitable and show an aptitude for engineering. It is stated that the intake into this scheme will be governed by the need to maintain the industry's complement of qualified craftsmen. Each division of the Coal Board will estimate its requirements at least once a year and will decide the number of apprentices to be taken on in each area. Vacancies will be notified at the collieries, workshops and other Coal Board undertakings, and at youth employment offices and technical colleges.

Economic Situation

On Friday last, in the House of Commons, during the debate on the address in reply to the Queen's Speech, the Chancellor of the Exchequer, Mr. R. A. Butler, gave an up-to-date review of the economic situation. In the course of his speech, the Chancellor said that the index of industrial production as a whole had been provisionally estimated at 125 to 126 points for September. That brought the average for the first nine months of this year to 118, which was between 4 and 5 per cent higher than during the corresponding period of last year, and 1 per cent or a little more above the level of 1951.

The Chancellor went on to say that an increase of something like 5 or 6 per cent in building output had made a significant contribution to the index for all industries, and that the output of vehicles had increased by about 6 per cent and chemicals by about 14 per cent. So far this year, the shipbuilding, engineering and electrical goods industries had only shown a relatively small increase although they remained above the 1951 level. That, Mr. Butler commented, was not too bad, but the Government wanted to see an improvement. The order book of the shipbuilding industry was 5,800,000 gross tons, which was more than four times the current annual rate of shipyard output. About this the Chancellor said that, whilst some of the smaller firms had anxieties about their order books, he could not feel that a figure of the kind he had given should lead to too great pessimism in the shipbuilding yards.

Employment and Unemployment

According to the Ministry of Labour's latest report on the employment situation in Great Britain, the total working population at the end of September numbered 23,483,000 (15,924,000 men and 7,559,000 women), which was 10,000 more than at the end of August. The number in civil employment at the end of September was 22,325,000 (14,897,000 men and 7,428,000 women).

Of those in civil employment at the end of September, 4,073,000 were at work in the country's basic industries. This figure showed a drop of 18,000 compared with the preceding month, the biggest decreases being seasonal ones in agriculture and road transport. Mining manpower, however, continued its downward trend during September, the number of wage earners on colliery books at the end of the month being 713,000, compared with 720,000 a year earlier. Employment in the manufacturing industries, on the other hand, increased during September by 53,000 to a total of 8,852,000. In the various manufacturing groups there were additions of 15,000 and 8000 respectively in the "engineering, metal goods and precision instruments," and vehicles, bringing their respective labour forces to 2,552,000 and 1,139,000. In civil employment outside the basic and manufacturing industries, the main changes were a decline of 24,000 in the number employed in professional, financial and miscellaneous services, and a decline of 6000 in the number of people engaged in the distributive trades.

Unemployment figures included in the Ministry's report relate to the position on October 12th, when 309,065 people were registered as out of work, compared with 291,970 on September 14th. The October figure, which represented 1·5 per cent of the total number of employees, included 10,111 who were described as being "temporarily stopped."

Railway Wages

Before it ceased to operate, at the end of September, the Railway Executive rejected a claim for a 15 per cent wage increase, which had been submitted on behalf of railway workers by the National Union of Railwaymen, the Associated Society of Locomotive Engineers and Firemen, and the Transport Salaried Staffs Association. This week the claim has been put before the Railway Staff National Tribunal, over which Sir John Forster presides, and which represents the industry's final court of appeal.

When the hearing began on Monday, Mr. J. S. Campbell, on behalf of the N.U.R., submitted that the main grounds for the claim were the cost of living, the difference between railwaymen's wages and those paid in industry, the railwaymen's right to share in the results of more efficient and economical working, and their right to be rewarded for higher productivity. It was imperative, he said, if serious difficulties were to be avoided in the railway industry, that rates of pay should be improved.

On Tuesday, Mr. W. P. Allen, on behalf of the British Transport Commission, told the Tribunal that to meet the present claims would mean an addition of £31,000,000 a year to the existing wages bill of the railways. The financial position, he said, was such that the unions' claims simply could not be met either in whole or in part.

Nickel Restrictions Removed

The Council of the Organisation for European Economic Co-operation has decided to suspend immediately the common list of restrictions in the use of nickel, nickel alloys and nickel-plating, and the application of measures limiting the use of nickel in case-hardening and constructional steels. Member countries of O.E.E.C. are at liberty to decide whether to suspend or maintain restrictions on the national level in accordance with their own requirements.

This action follows a decision by the International Materials Conference that the allocation of nickel should end on September 30th, the gap between supply and demand having narrowed sufficiently to permit such a step. It may be recalled that the common list of end-use prohibitions for nickel, nickel alloys and nickel-plating, containing nearly 500 articles for which the use of these materials was forbidden, was adopted by the O.E.E.C. in May, 1952, when world shortages made it necessary to reserve available nickel supplies for defence purposes. At that time it was pointed out that the adoption of a common list made possible the co-ordination of restrictive measures taken by Governments; it also helped to avoid difficulties in connection with the liberalisation of trade by reducing the risk of undesirable commercial repercussions to a member country which had forbidden the production of certain articles in its own factories.

In the light of the O.E.E.C. decision, the Board of Trade and the Ministry of Supply have removed, as from November 6th, all restrictions on the use of nickel in the United Kingdom. The necessary revocation orders have been published, and the Minister of Supply has withdrawn the alloy steel directions restricting the use of nickel in the manufacture of alloy steels.

Notes and Memoranda

Road and Rail

FORTH BRIDGE ADVISORY PANEL.—The Minister of Transport and Civil Aviation has appointed a panel of experts to advise him on a proposal for a road bridge over the present Forth railway bridge. The members of the panel are Professor J. F. Baker, D.Sc., head of the engineering department of Cambridge University ; Mr. Gilbert Roberts, M.I.C.E., of Messrs. Freeman, Fox and Partners, and Mr. H. Shirley Smith, M.I.C.E., of Cleveland Bridge and Engineering Company, Ltd.

ROAD ACCIDENTS.—Reports so far received by the Ministry of Transport and Civil Aviation show that road casualties in September totalled 20,415, nearly 2300 more than in September, 1952. There were 436 deaths, an increase of 15, and 4991 were seriously injured, an increase of over 600. In August, the peak month for holiday traffic, casualties totalled 22,103, or 858 more than in the previous August. There were 457 deaths, an increase of 19, and 5408 were seriously injured, an increase of 206.

Air and Water

APPRENTICES EXAMINATION AWARDS.—Forty-one members of the apprentice training scheme in the Hayes Group of factories of The Fairey Aviation Company, Ltd., are to be presented with cash prizes by the company in recognition of examination successes over the past twelve months. Apprentices, who obtained Higher National Certificates, each receive a cheque for £10 and others receive £5 to mark success in the Ordinary National Certificate Examination, the City and Guilds Intermediate Machine Shop Engineering and Sheet Metal Work courses.

SHELL TANKERS, LTD.—We are informed by the Shell Petroleum Company, Ltd., that a new company, Shell Tankers, Ltd., has been formed and became operative on November 1st, to deal with the management and operation of the Shell fleet, which will continue to be owned by the Anglo-Saxon Petroleum Company, Ltd. Mr. J. W. Platt, is chairman of the new company and Mr. A. S. C. Hulton is managing director, and the following have been appointed directors : Sir Francis Hopwood, Messrs. J. Lamb, W. F. Pascoe, J. H. Kirby, A. Logan, and A. J. Ryecroft and Captain H. B. Russell.

WRECK RETURNS.—The returns of merchant ships totally lost, broken up, &c., for the quarter ended March 31, 1953, have been published by Lloyd's Register of Shipping. Steamships and motorships totally lost consequent upon casualty in the world amounted to fifty-six ships of 106,250 tons gross, including thirteen ships of 33,933 tons belonging to Great Britain and Northern Ireland, and three ships of 656 tons owned by the other Commonwealth countries. The corresponding totals of steamships and motorships condemned, broken up, &c., not consequent upon casualty were respectively 106 ships of 261,866 tons gross, thirty ships of 51,283 tons, and nine ships of 29,766 tons.

ACTIVITY AT UNITED KINGDOM AND CHANNEL ISLAND AERODROMES.—Air transport movements at United Kingdom aerodromes in September, 1953, numbered 23,800, approximately 9 per cent more than in September, 1952. The total of passengers handled was 443,000, 22 per cent more than in September, 1952. Freight on and off-loaded amounted to 8300 short tons, an increase of 77 per cent on the corresponding month of the previous year. The rise in freight figures over those of September, 1952, was caused mainly by the increases in cross-Channel car ferry traffic. Freight and vehicles handled at Lympne amounted to 3900 short tons compared with 1700 short tons in September, 1952. Passenger movements at Lympne also showed a rise of 147 per cent over the corresponding figures for September of last year. London and Northolt Airports together handled 235,000 passengers, 17 per cent more than in September, 1952. Other airports at which passenger traffic increased considerably over September, 1952, were Edinburgh (Turnhouse), 5500 (35 per cent increase) ; Birmingham (Elmdon), 8600 (32 per cent increase) ; Southampton (Eastleigh), 11,700 (30 per cent increase) ; Glasgow (Renfrew), 22,000 (20 per cent increase) ; Manchester (Ringway), 25,000 (17 per cent increase), and Prestwick, 22,000 (16 per cent increase).

Miscellanea

STOCKWELL BUS GARAGE.—In our issue of October 30th, a description was given of the London Transport Executive's new garage at Stockwell. We omitted to mention that the architects for this structure were Adie, Button and Partners in association with Thomas Bilbow, architect to the London Transport Executive.

A MACHINE TOOL DEMONSTRATION.—A demonstration of modern machine tools and equipment is to be held by Alfred Herbert, Ltd., at 208, Corporation Street, Birmingham, 4, from Monday next, November 16th, till Saturday, November 21st, from 10 a.m. to 6 p.m. daily. This demonstration will include high-speed bar work on automatics, horizontal milling and centreless grinding, and inspection work with Sigma instruments.

OPENING OF MECCA POWER STATION.—The first power station to provide Mecca with a public supply of electricity was opened by H.R.H. the Crown Prince of Saudi Arabia on October 22nd last. The station has a capacity of 3740kW which will be increased later to 10,000kW. At present it is equipped with four Mirrlees-Brush diesel-electric generating sets. Supplies will be available for street and house lighting and for industrial use.

SMITHFIELD SHOW.—The Smithfield Show and Agricultural Machinery Exhibition will be held at Earls Court, London, from Monday to Friday, December 7th to 11th. On the first day, the exhibition will open at 9 a.m., and on the succeeding days at 10 a.m., the closing time each day being 7 p.m. There will be 370 exhibitors in the machinery and equipment section. The exhibition is organised by the Smithfield Show Joint Committee, 148, Piccadilly, London, W.1.

IRON AND STEEL PRICES.—The Minister of Supply has decided, after consulting the Iron and Steel Board, that it is no longer necessary to control the maximum prices of vertically cast and spun iron pipes and special iron castings, cast iron drain pipes and fittings, forged alloy, gun billets, railway tyres, wheels and axles, and other forgings, under Defence (General) Regulations. He has therefore made an Order removing these products from statutory price control. The Order became effective on November 4th.

BRITISH PLASTICS FEDERATION.—We learn that the information bureau operated by the British Plastics Federation is now dealing with over 5000 inquiries a year. As part of its information service abstracts from about 150 journals are regularly classified for reference and are also published and circulated by subscription to most countries. Twelve monthly issues are published in two forms—printed on one side only, so that they can be pasted up into a form of card index, or printed on both sides. The charge for each is 10 guineas per annum, post free, from the Federation offices, 47, Piccadilly, London, W.1.

SEMI-MANUFACTURES OF COPPER AND COPPER BASED ALLOYS.—The Monopolies Commission is now examining the arrangements in the semi-manufacturing of copper and copper-based alloy industry to see whether those industries operate or may be expected to operate against the public interest. The Commission's terms of reference include copper, brass, bronze and nickel silver in the common forms such as sheet, strip, wire, tubes, rods and sections. We are informed that the Commission would welcome statements from manufacturers, merchants, importers and exporters who rely on a supply of these products for their business.

CHEMICAL INDUSTRY POLLUTION STUDY.—The Organisation for European Economic Co-operation has arranged for a technical assistance mission to visit a number of European countries to study methods of dealing with air and water pollution caused by the chemical industry. The mission consists of officials and industrialists concerned with these problems from Austria, Belgium, France, Germany, Portugal, Sweden, the United States, and the United Kingdom. It will report on the best European practice and it may subsequently be decided to organise a mission to study this pollution problem in the United States.

INSTALLATION AND CARE OF ELECTRIC MOTORS.—A seventy-four-page pocket book dealing with the installation and care of B.T.H. electric motors has been published by the British Thomson-Houston Company, Ltd., Rugby. This first edition of the pocket book is concerned with industrial motors from about 1 h.p. to 40 h.p. It contains chapters on installation, care and maintenance, faults and their diagnosis, renewals and spares, and miscellaneous data about the choice of motors and their performance. Firms can obtain the pocket book (serial G 13751) by applying on their letter headings to the above address, indicating the type of B.T.H. machines installed.

TUNGSTEN CARBIDE BARS.—Particulars have been received from Flexible Drives (Gilmans), Ltd., 195, High Street, Smethwick, Staffs, of a wide range of tungsten carbide bars the firm is now making for use with its rotary flexible drive machines. These tungsten carbide bars, which are stated to be suitable for cutting steels up to a hardness of Rockwell 65*c*, are machine ground from the solid to ensure balance and uniformity of tooth spacing and cutting angles. Their resharpening calls for special equipment and the makers have introduced a grinding service for this purpose. The higher speeds required when using the new tungsten carbide bars are available with the recently introduced "Flexmaster" machine described in our issue of March 20, 1953.

BOILER EXPORTS TO CANADA.—The British Standards Institution has set up a section to deal with the approval in the United Kingdom of air receivers, boilers and pressure vessels intended for export to Canada. Initially the B.S.I. and the chief of the boiler inspection department of Quebec drew up arrangements to cover the necessary service and these have now been extended by agreement with the Canadian Standards Association's committee on Canadian boiler regulations to all Canadian Provinces, whose chief inspectors have agreed to accept equipment manufactured in the United Kingdom provided that the necessary registration with Canada has been effected ; the equipment has been constructed in accordance with the relevant Canadian specifications, and the necessary inspection during and after construction has been carried out by an accepted inspection agency. The section of B.S.I. dealing with this matter has been set up in association with the B.S.I./C.S.A. Approvals Agency for electrical equipment so that it will be convenient for United Kingdom manufacturers of equipment who have to comply not only with the Canadian Electrical Code, but also with the requirements of pressure vessels such as electrode boilers and electrically operated pressure vessel accessories. As the staff of this section of B.S.I. is familiar with conditions in the engineering industry in Canada, manufacturers are invited to apply to the Institution for full information and help.

CYRIL JOHN SARJEANT.—We regret to announce the death, on November 3rd, of Mr. C. J. Sarjeant, who, before his retirement in 1949, was manager of control gear engineering department, the British Thomson-Houston Company. He was born at Balham on August 10, 1891, and received his technical education at Battersea Polytechnic. He joined the British Thomson-Houston Company, Ltd., in 1911 as an assistant in the test department. During the first world war he joined the Royal Field Artillery and served in Gallipoli and France. He rejoined the B.T.H. test department in 1919 and a few months later transferred to control gear engineering department. In 1925, Mr. Sarjeant went to South Africa to supervise the final installation of the 3000V d.c. automatic substations of the South African Railway electrification. He was appointed manager of the control gear engineering department in 1947, succeeding Mr. H. C. Hastings.

HANDBOOK ON DIE CASTINGS.—A handbook on die castings which has been sponsored by the Advisory Committee (Die Castings), Ministry of Supply, has been compiled by Mr. F. D. Penney, of the Ministry's Armament Design Establishment. This book is intended primarily to assist the designer to appreciate the advantages and limitations of die casting processes ; assess the suitability of a particular component for production as a pressure or gravity casting ; choose the best materials available, and to give guidance in designing the component in order that full advantage may be taken of the potentialities of the process and the materials chosen. It will also be of value to those concerned with the production and inspection of die castings, both for the Services and general usage. The handbook is fully illustrated with photographs and line drawings and also contains tables giving data on compositions, physical and mechanical properties of die casting alloys, on limiting sizes and recommended tolerances. It is published by Her Majesty's Stationery Office at 6s. net.

Personal and Business

FAIRMAN PRECISION TOOLS AND PRODUCTS, Ltd., Victory Works, Horley, Surrey, states that its telephone number is Horley 3678.

MR. D. C. G. LEES has left the staff of the Aluminium Development Association to become development engineer of Aluminium Union, Ltd.

SOLIGNUM, Ltd., Donington House, Norfolk Street, London, W.C.2, states that Mr. G. W. Robertson, sales manager, has been appointed a director.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., announces that on November 23rd its Bristol branch will be transferred to 7–9, Barton Street, Bristol.

AIR COMMODORE G. J. POWELL, managing director of Silver City Airways, Ltd., has been re-elected chairman of the British Independent Air Transport Association.

DR. FRANCIS F. JARAY, consultant on chemical plant and corrosion proof materials, has opened a new office at 6, Sansome Place, Worcester (telephone, Worcester 5369).

ROUNDHAY METAL FINISHERS (LEEDS), Ltd., is the new title of the firm hitherto known as Rushtons (Leeds), Ltd. The firm continues to operate from Olympia Works, Roundhay Road, Leeds, 8.

THE UNION-CASTLE MAIL STEAMSHIP COMPANY, Ltd., announces that it has appointed Mr. S. Barr, general manager, to be a director to fill the vacancy caused by the death of the Duke of Abercorn.

THE BRITISH PRODUCTIVITY COUNCIL states that Mr. G. M. Flather, joint managing director of W. T. Flather, Ltd., Sheffield, has been nominated as a director of the National Industrial Fuel Efficiency Service.

THE LONDON COUNTY COUNCIL announces the appointment of Mr. F. G. West, A.R.I.B.A., as senior architect, general division, in succession to Mr. W. J. Durnford, F.R.I.B.A., who will retire at the end of January, 1954.

MR. L. A. RAYMOND has been appointed general superintendent of communications for the eastern region of the Canadian Pacific Railway, in succession to Mr. L. E. Hamson, who has become assistant general manager of the region.

THE HOFFMANN MANUFACTURING COMPANY, Ltd., states that Mr. P. Rhodes is retiring on December 31st from his position as London area manager, after thirty-two years in the company's service. He will be succeeded by Mr. S. G. M. Shallard, who is at present deputy manager of the London area.

BRUCE PEEBLES AND CO., Ltd., Edinburgh, 5, announces the following appointments :—Mr. V. P. Mackay, manager, rotating plant department ; Mr. R. W. Flux, manager, and Mr. D. H. Smith, chief designer and deputy manager, transformer department ; Mr. O. L. Robson, manager, rectifier department.

MR. F. H. ROLT, M.I.Mech.E., formerly superintendent of the metrology division of the National Physical Laboratory, has consented to act as consultant in metrology to Coventry Gauge and Tool Company, Ltd., Taylor, Taylor and Hobson, Ltd., Hilger and Watts, Ltd., and the Brooke Tool Manufacturing Company, Ltd.

THE MINISTRY OF SUPPLY states that Mr. R. H. Weir is to become principal director of engine research and development on January 1st next. He will succeed Air Commodore F. R. Banks, C.B., who will then be returning to his firm, the Associated Ethyl Company, Ltd. Air Commodore Banks will continue to act as a consultant to the Ministry on aero-engines.

British Patent Specifications

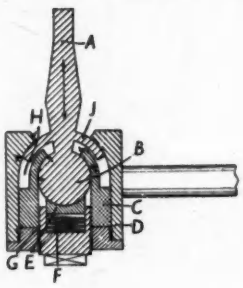
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2 2s. 8d. each.

BEARINGS AND SUPPORTS

698,473. August 23, 1951.—Ball and Socket Joint, Thorleif Stokke, 113, Madlavegen, Stavanger, Norway, and Conrad Bethin Olsen, 3, Nedre Slottsgate, Oslo, Norway.

The invention concerns ball and socket joints of the type comprising a rod with a ball at one end in a housing enclosing the ball in such a way that the rod simultaneously can perform a rotating and pendulating movement around its axis. The drawing shows a



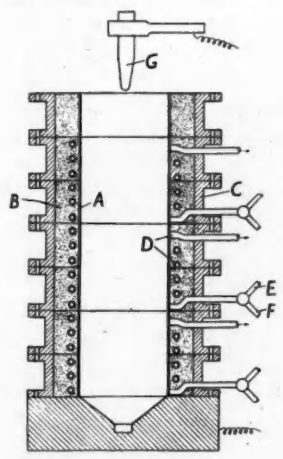
No. 698,473

rod *A* with a ball *B* at one end. The ball is housed in a housing consisting of two parts *C* and *D*, the inner part being so shaped that its upper portion fits closely around a portion of the upper half of the ball in such a way that the rod, besides rotating around its axis also, is permitted to perform a swinging movement. Further the ball is supported on a spherical bearing *E*, which is pressed against the ball by means of a spring *F*. A spring wire in a groove *G* in *D* prevents the part *C* from falling out on removing the bottom piece. Between the inner and the outer parts of the housing is an annular recess *H* limited by spherical surfaces concentric with the ball. Above the ball the rod is provided with a spherical flange *J*, which fits into the annular recess, the flange being able to follow the rotating and pendulating movement of the rod. An alternative design is also given in the specification and methods of manufacture are also described.—*October* 14, 1953.

METALLURGY

698,303. November 1, 1951.—Production of Steel Ingots, Bochumer Verein für Gussstahl-Fabrikation Aktiengesellschaft, Stahlhauserstrasse 20, Bochum, Germany.

The invention describes an inductively heated mould which is constructed as a coreless induction furnace and charged with alternating current of low power and low frequency, for example, of 50 cycles per second, cooling being effected by



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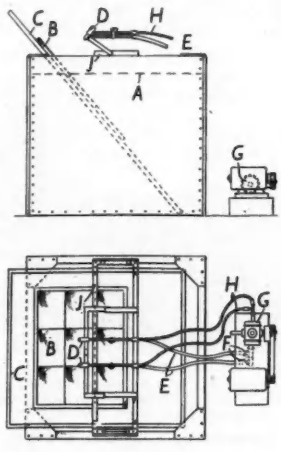
water flowing through a cooling tube in order to prevent a temperature increase, whereafter the steel is solidified with a reduced current supply. As shown in the drawing, the thin sheet metal jacket *A* forms the inner boundary of the casting mould. A layer of dry sand *B*, capable of trickling, is introduced between the sheet metal jacket *A* and the outer armouring *C*. Embedded in the layer of sand is the cooling coil *D* situated at a relatively small distance from the sheet metal jacket, the coil being divided into three sections in the constructional example. Each section of the cooling coil has a feed duct *E* for compressed air and a feed duct *F* for water. The cooling coil may, if desired, serve simultaneously to feed induction current, especially of low frequency, about the solidifying ingot. When the completely assembled mould has been dried, for example, by heating to 160 deg. to 200 deg. Cent., the casting commences, compressed air being employed as cooling medium for the cooling coil. When the temperature of the steel has fallen the cooling is intensified by mixing water with the compressed air and finally by employing cooling water alone. The use of water alone may commence, for example, when the temperature of the coil has fallen approximately to the boiling point of the water. With such a method of operation, in which the temperature of the coil is initially high, no water of condensation is initially formed within the lining. There is no possibility of explosion, but the very distinct advantage is afforded of being able to vary the cooling speeds in the individual zones of the ingot. The head of the ingot can be heated by an electrode *G*, which can be lowered into contact with the liquid steel in the mould so that the ingot solidifies from the bottom upwards.—*October* 14, 1953.

698,416. June 28, 1950.—Annealing Copper and Copper Alloys, Hayne-Ingleby, Ltd., 69, Riverbank, Laleham Road, Staines, Middlesex. (*Inventors: Sidney Richard Williams and Robert Gordon Earle Harris.*)

As the drawing shows, the annealing apparatus comprises a water tank about 5ft long, 5ft wide and 4ft high filled almost to the top with water, the water level being shown as *A*. The tank is open at the top; a ramp 3ft wide composed of firebrick *B* mounted on a steel framework *C* and inclined at an angle of about 45 deg., extends up from the bottom of the tank to about 2ft above the water level. The slope of the ramp is not critical but 45 deg. has been found to be convenient for feeding the material down the ramp by hand. Two burners *D* are used, each employing coal gas and air; the gas is fed to the burners through pipes *E*, the quantity being controlled by cocks *F*. The air is delivered by a compressor *G* through pipes *H*. The burners are supported by a steel frame *J*; they are about 9in apart and direct the flame on to the surface of the water just in front of the ramp. The burners direct the flame downwards at an angle of 45 deg. to the surface of the water and they strike the surface of the water and are deflected along the water and up the ramp. The burners are about 1ft away from the surface of the water; between them they use



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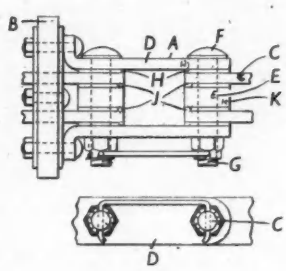
about 1100 cubic feet of coal gas per hour, and the width of the flame, and the quantity of air used, are adjusted to give a continuous flame 12in wide. The colour of the flame most suited for any material can be readily discovered by experiment; the flame should preferably be non-oxidising, or at least not highly oxidising. When using copper strip up to ¼in thick or sheets up to ½in thick, the strip or sheet is fed by hand slowly and evenly down the ramp through the flame into the water, the rate of movement being adjusted so that the copper in the flame achieves a red colour. The brightest results are secured when the firebrick of the ramp has itself become red hot. On removing the strip or plate from the water, it is preferably fed straight into a drying chamber, so that the water is quickly dried off.—*October* 14, 1953.

POWER TRANSMISSION

671,424. August 23, 1949.—Endless Driving and Conveyor Chains, Henry Waldemar Hapman, 15042, Biltmore Drive, Detroit 27, Michigan, U.S.A.

In the form of the invention shown, a conveyor drive has a chain *A*, a series of resilient rubber or rubber composition flight elements *B* spaced on it at equal distances. The conveyor chain includes inner and outer chain links *C* and *D*, with apertures for receiving a bolt *E* having a head *F* and a threaded end portion *G*. Synthetic rubber or rubber composition washers *H* and *J* are interposed between the



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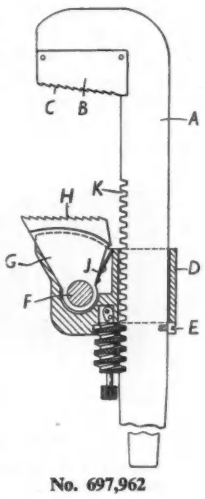
inner and outer chain links as well as between the inner links and rollers *K*. The synthetic rubber washers may be formed of a neoprene or butadiene having a wax solvent to lubricate automatically the mutual bearing surfaces of the chain parts, or any other rubber composition which will resist the action of chemicals and will form a tight sealing joint between the side bars or links of the chain as well as the bearing surfaces of the pins and the rollers, so as to exclude abrasive material from the bearing surfaces and prevent excessive wearing thereof. The conveyor flight element *B* includes yielding synthetic rubber or rubber composition flight elements sandwiched between clamping plates which are held in place on lugs.—(*Amended specification*), *May* 7, 1952.

TOOLS AND WORKSHOP APPLIANCES

697,962. June 7, 1950.—Pipe Wrenches, Francis William Macdonald Matthews, formerly of 27, Bedford Square, Brighton, Sussex, and now of Petit Coin, Rozel Bay, Jersey.

The wrench described comprises a shank *A* having a jaw *B* of hardened steel fixed to one end. The jaw has a slightly oblique serrated surface *C*. A carriage *D* slides along the shank and a cheese-headed screw *E* in the back of the shank normally limits its movement. A hinge pin *F* in the carriage has pivoted on it a movable jaw *G* having a serrated surface which is more or less parallel to the surface *C*. A leaf spring *J* attached to the jaw *G* urges it away from the shank. The centre line of the pin *F* is nearer to the shank than the centre of curvature of the surface *H*, so that a movement of the jaw about the hinge pin gives the necessary wedging action on a pipe. The shank has a rack *K* cut in its edge towards the jaws for adjustment of the position of the carriage. As shown in the drawing a quick release is also provided.—*October* 7, 1953.



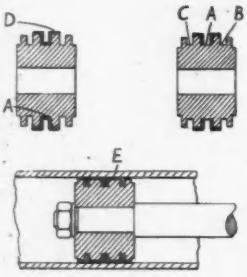
No. 697,962

HYDRAULIC MACHINERY

698,346. December 13, 1950.—Pistons for Fluid-Operated Jacks, The Hymatic Engineering Company, Ltd., Glover Street, Redditch, Worcestershire. (*Inventor: Ronald Bernard Elliott.*)

The object of the invention is to provide improved means which prevent the scoring of the cylinder by the piston when the cylinder is made from a low-density metal, such as aluminium or magnesium alloy. The accompanying drawings show three

forms of piston with sleeves made in accordance with the invention. The main seal of the piston is located in the peripheral groove *A*, which, as shown in the upper right-hand view, has its opposite walls covered with sleeves *B* of rubber or plastic bonded to the piston. Such sleeves extend over the peripheral surface of the piston between the groove *A* for the main seal and



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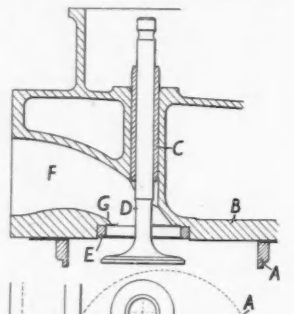
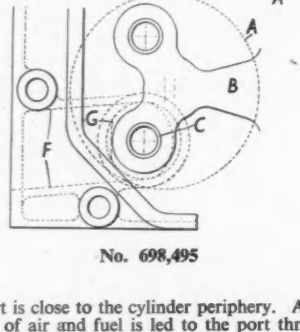
the grooves *C* for the usual lubrication wipers. In the construction shown in the adjacent drawing the rubber or plastic sleeve *D* covers also the base of the peripheral groove *A*. In the construction illustrated in the lower view the rubber or plastic sleeve *E* covers the peripheral surface of the piston, but does not extend into the groove for the main piston seal and lubrication wipers.—*October* 14, 1953.

INTERNAL COMBUSTION ENGINES

698,495. October 12, 1950.—Construction of CYLINDER HEADS, Leyland Motors, Ltd., Suffolk House, Laurence Pountney Hill, London, E.C.4, and Norman Tattersall, of Leyland Motor Works, Leyland, Lancashire.

The invention relates to an improved construction of cylinder head for an internal combustion engine, and particularly to a formation of inlet port in which a lip terminating the inlet channel and extending over the outline of the valve seating contributes to the swirl imparted to the incoming air or gases. In the drawings the cylinder is indicated at *A* and the cylinder head at *B*. In the head is a guide *C* for the inlet valve *D*. The valve seats upon an inlet port in the flat inner face of the head with an inset seating *E*.





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The port is close to the cylinder periphery. Air or a mixture of air and fuel is led to the port through a channel *F* in the head. As shown in the lower view, this channel is not directed towards the centre of the cylinder; the projection of its mid line upon the inner surface of the head may be at right angles to a radial line from the axis of the cylinder to the centre of the valve seating, or, as shown, at a somewhat greater angle. The lower wall of the channel *F* is prolonged over the edge of the valve seating to form a lip *G*, which may have a straight edge as shown in the drawing or a slightly curved edge nearly at right angles to the projection of the mid line of the channel upon the face of the head, but making with that projection a slightly acute angle on the side next the cylinder axis. The remainder of the channel wall may be smoothly curved to an end surface directed towards the inner edge of the valve seating.—*October* 14, 1953.

Launches and Trial Trips

ARAMIS, oil tanker; built by the Chantiers et Ateliers de Saint-Nazaire-Penhoët for the Société Mazout-Transports; length between perpendiculars 600ft, breadth moulded 82ft 6in, depth 42ft 6in, deadweight 27,000 tons, trial speed 16·5 knots; one set of triple-expansion double reduction geared turbines, normal horsepower 12,500 s.h.p. at 112 r.p.m. of propeller, maximum power 13,750 s.h.p. at 115 r.p.m.; steam is produced at 640 lb per square inch at 805 deg. Fah. by two Penhoët "P.41" oil-fired boilers. Trials, October.

BRITISH OAK, oil tanker; built by Smith's Dock Company, Ltd., for the British Tanker Company, Ltd.; length between perpendiculars 515ft, breadth moulded 69ft 6in, depth moulded 37ft 6in, deadweight 15,882 tons on 30ft 0½in draught, service speed 13¼ knots; twenty-seven cargo oil tanks, two pump rooms, four 500 tons per hour cargo oil pumps, steam deck machinery, two 150kW diesel generators, one 75kW steam-driven generator, two oil-fired exhaust gas boilers; Harland and Wolff six-cylinder, two-stroke, single-acting, opposed-piston diesel engine, 6400 b.h.p. at 114 r.p.m. Trial, October.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Tues., Nov. 17th.—Magnet House, Kingsway, London, W.C.2, "Electrical Developments in Horticulture," F. E. Rowland. 6.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Tues., Nov. 24th.—W. MIDLANDS SECTION: Technical College, Wulfruna Street, Wolverhampton, "Remote Control Devices and Servo-Mechanisms," A. E. W. Hibbitt, 7.15 p.m.

CHEMICAL SOCIETY

Thurs., Nov. 19th.—LONDON BRANCH: Institution of Civil Engineers, Great George Street, London, S.W.1, "Some Applications of the Separation of Large Molecules and Colloidal Particles," A. Tiselius, 7.30 p.m.

INCORPORATED PLANT ENGINEERS

Mon., Nov. 16th.—MERSEYSIDE AND NORTH WALES BRANCH: Radiant House, Bold Street, Liverpool, "Fan Engineering," R. H. Holbeche, 7.15 p.m.

Tues., Nov. 17th.—SOUTH WALES BRANCH: South Wales Institute of Engineers, Park Place, Cardiff, "Mechanical Handling," 7.15 p.m.

Wed., Nov. 18th.—GLASGOW BRANCH: Scottish Building Centre, 425–427, Sauchiehall Street, Glasgow, C.2, "Heat Transfer," R. A. Brecknell, 7 p.m.——KENT BRANCH: Bull Hotel, Rochester, "Concrete," E. Davis, 7 p.m.

Thurs., Nov. 19th.—BLACKBURN BRANCH: Grosvenor Hotel, Lond Street, Blackburn, "Electrical Hazards," D. A. Picken, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Thurs., Nov. 19th.—KINGSTON-UPON-HULL AND E. MIDLANDS' SECTION: Royal Station Hotel, Kingston-upon-Hull, "Burning of Boiler Oil in Two- and Four-Stroke Cycle Diesel Engines and Development of Fuel Injection Equipment," A. G. Arnold, 7.30 p.m.——N.E. COAST SECTION: Technical College, Sunderland, "Petroleum Refining," E. J. Boorman, 7 p.m.

Fri., Nov. 20th.—MERSEYSIDE AND N.W. SECTION: City Technical College, Liverpool, "Launching of Ships," R. S. Hogg, 7 p.m.

INSTITUTE OF NAVIGATION

Fri., Nov. 20th.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Navigation on the U.K. to New Zealand Air Race," 5 p.m.

INSTITUTE OF PETROLEUM

Tues., Nov. 17th.—STANLOW BRANCH: Grosvenor Hotel, Chester, "Additives for Petroleum Lubricants," F. F. Musgrave, 7.30 p.m.

Sun., Nov. 22nd.—STANLOW BRANCH: Tatler Theatre, Chester, Film Show, 2.30 p.m.

INSTITUTE OF REFRIGERATION

Tues., Nov. 17th.—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, "Freeze Drying," R. A. Kekwick and R. F. Strickland-Constable, 5.30 p.m.

INSTITUTE OF TRANSPORT

Mon., Nov. 16th.—Jarvis Hall, 66, Portland Place, London, W.1. "The Short Sea Trade," R. G. Grout, 5.45 p.m.

INSTITUTE OF WELDING

Thurs., Nov. 19th.—N. LONDON BRANCH: The Polytechnic, Regent Street, W.1, "Productivity in the Fabrication of Structural Steelwork," D. C. Dixon, 7.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Wed., Nov. 18th.—York Hall, Caxton Hall, Caxton Street, London, S.W.1, Film, "The Stanlow Story," introduced by E. Le Q. Herbert, 5.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Nov. 17th.—ORDINARY MEETING: Great George Street, Westminster, London, S.W.1, "Construction of Two Concrete-Lined Tunnels for the Machkund Hydro-Electric Project, South India," G. A. Gauld and R. J. Newport, 5.30 p.m.

Fri., Nov. 20th.—YORKSHIRE ASSOCIATION: Hotel Metropole, Leeds, "Atmospheric Pollution: Causes, Effects and Prevention," A. Parker, 7 p.m.

Tues., Nov. 24th.—RAILWAY MEETING: Great George Street, Westminster, London, S.W.1, "Bridge Investigation, Ceylon Government Railways, 1949–1951," Conrad Gribble, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Nov. 16th.—INFORMAL MEETING: Savoy Place, London, W.C.2, Discussion on "Illuminations and Decorative Lighting," opened by H. Carpenter, 5.30 p.m.

Tues., Nov. 17th.—MEASUREMENTS SECTION: Savoy Place, London, W.C.2, "Alternating-Current-Instrument Testing Equipment," A. H. M. Arnold, 5.30 p.m.——LONDON STUDENTS' SECTION: Public Library, Chelmsford, "Metallic Resistance at High Frequency," A. D. Stevens, 7 p.m.——N. MIDLAND CENTRE: British Electricity Authority, 1, Whitehall Road, Leeds, 1, "The Technique and Development of Automatic Winding in Mine Shafts," B. L. Metcalf and G. Cuttle, 6.30 p.m.

Thurs., Nov. 19th.—UTILIZATION SECTION: Savoy Place, London, W.C.2, "The Wear of Carbon Brushes at High Altitudes," R. F. Sims, 5.30 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Mon., Nov. 16th.—WOLVERHAMPTON BRANCH: Compton Grange, Compton Road, Wolverhampton, "Precision (Lost Wax) Castings," W. N. Jones, 7.30 p.m.

Wed., Nov. 18th.—DUNDEE BRANCH: Royal British Hotel, Dundee, "Principles of Measurement," G. V. Stabler, 7.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Nov. 17th.—39, Elmbank Crescent, Glasgow, "Fluid Flow in Turbo-Machinery," H. S. Fowler and V. Walker, 6.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., Nov. 18th.—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, "Developments in Locomotive Testing," S. O. Ell, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Nov. 13th.—GENERAL MEETING: Storey's Gate, St. James's Park, London, S.W.1, "The Synthesis of Two Marine Water-Tube Boilers," L. Baker, 5.30 p.m.

Mon., Nov. 16th.—MIDLAND BRANCH GRADUATES' SECTION: James Watt Memorial Institute, Birmingham, "Space Flight," R. Shaw, 7 p.m.

Tues., Nov. 17th.—EASTERN BRANCH, GRADUATES' SECTION Visit to Cliff Quay Generating Station, B.E.A., Ipswich, 7 p.m ——WESTERN BRANCH, Grand Hotel, Broad Street, Bristol, "Recent Developments in the Machinability of Steel," K. J. B. Wolfe, 7 p.m.

Thurs., Nov. 19th.—MIDLAND BRANCH: James Watt Memorial Institute, Birmingham, "The Influence of Industrial Design on Engineering," F. D. Hollister and John Barnes, 6 p.m.——N.W. BRANCH, INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP: Engineers' Club, Albert Square, Manchester, "Developments in Steel Castings in the Heavy Power Plant Industry," F. Buckley, 6.45 p.m.

Fri., Nov. 20th.—GENERAL MEETING: Storey's Gate, St. James's Park, London, S.W.1, "Relaxation Methods: A Retrospect," Sir Ricaard Southwell, 5.30 p.m.——N.E. BRANCH GRADUATES' SECTION: Grey Hall, King's College, Newcastle upon Tyne, "Astronomy," T. W. James, 6.30 p.m.——SCOTTISH BRANCH, GRADUATES' SECTION: Royal Technical College, Glasgow, "Some Aspects of the Repair and Overhaul of Aero-Engines," P. Hanretty, 7.30 p.m.——SOUTHERN BRANCH, GRADUATES' SECTION: Municipal Technical College, Bournemouth, "Servo-Mechanisms," R. A. Middleton, 7.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Nov. 13th.—W. WALES SECTION: Central Public Library, Alexandra Road, Swansea, "Noise and Vibration in Machinery," W. A. Tuplin, 7 p.m.——E. COUNTIES SECTION: Diocesan Hall, Tower Street Ipswich, "Transport for an Engineering Works," E. N. Farrar, 7.30 p.m.

Mon., Nov. 16th.—MANCHESTER SECTION: Reynolds Hall, College of Technology, Sackville Street, Manchester, "Modern Power Plants for Helicopters," A. G. Forsyth, 7.15 p.m.—— N.E. SECTION: North of England Institute of Mining and Mechanical Engineers, Neville Hall, Newcastle upon Tyne, "The Use of Radial Drilling Machines for Boring Work," 7 p.m.

Tues., Nov. 17th.—HALIFAX SECTION: George Hotel, Huddersfield, "The Design, Manufacture and Use of 5in Sliding, Surfacing and Screwcutting Lathes," D. H. Turnbull, 7.15 p.m.

Wed., Nov. 18th.—BIRMINGHAM SECTION; James Watt Memorial Institute, Great Charles Street, Birmingham, 3, "The Acnievement of High Precision in Quantity Production," J. Smedley, 7 p.m.——DUNDEE SECTION: Mathers Hotel, Dundee, "Watchmaking," A. W. Marshall, 7.30 p.m.——EDINBURGH SECTION: North British Station Hotel, Edinburgh, "Tyre Manufacture," A. J. Mactaggart, 7.30 p.m.——GLOUCESTER AND DISTRICT SECTION: Bell Hotel, Gloucester, "Application of Motion Study," Miss A. G. Shaw, 7.15 p.m.

Thurs., Nov. 19th.—GLASGOW SECTION: Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, "Metal Finishing and Hard Coating," S. A. J. Murray, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Tues., Nov. 17th.—SCOTTISH BRANCH: Ca'doro Restaurant, Glasgow, "Examples of Structural Steel Design to B.S. 449," V. H. Lawton, 6 p.m.

Wed., Nov. 18th.—YORKSHIRE BRANCH: Great Northern Hotel, Leeds, "Prestressed Concrete Beams at London Airport," A. J. Harris, 6.30 p.m.

INSTITUTION OF WATER ENGINEERS

Wed., Nov. 18th.—Institution of Civil Engineers, Great George Street, London, S.W.1, "Construction of Wells and Boreholes," H. A. P. Hetherington, 2.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Nov. 13th.—ORDINARY MEETING: Townsend House, Greycoat Place, London, S.W.1, "Post-War Ship Design and the Future," C. A. Hobson, 7 p.m.

Fri., Nov. 20th.—ORDINARY MEETING: Townsend House, Greycoat Place, London, S.W.1, Chairman's Address, "A Consulting Engineer's Casebook," S. R. Broderick, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, Nov. 13th.—Engineers' Club, Albert Square, Manchester, "Modern Application of Reinforced Concrete to Industrial Buildings," M. B. Watson, 6.45 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Nov. 13th.—Mining Institute, Newcastle upon Tyne, "Some Observations from 16in Propeller Tests in the New King's College Cavitation Tunnel," L. C. Burrill and Arnold Emerson, 6.15 p.m.

ROYAL AERONAUTICAL SOCIETY

Thurs., Nov. 19th.—4, Hamilton Place, London, W.1, "Aircraft Stability and Control," A. W. Babister, 7 p.m.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS

Mon., Nov. 16th.—The University Building, St. George's Square, Sheffield, "Indentation Hardness," D. Tabor, 7.30 p.m.

SOCIETY OF CHEMICAL INDUSTRY

To-day, Nov. 13th.—CORROSION GROUP: Institution of Electrical Engineers, Savoy Place, London, W.C.2, "A Symposium on Cathodic Protection," 9.45 a.m.